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Operational efficiency of decentralized hog marketing in Iowa

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by

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I. INTRODUCTION

Section A of chapter one develops the historic relationship between market structure changes that have been made possible by or caused by changes in transportation and production technology. Section B states the purpose and the hypotheses of this study.

A. Historical Development

1. Terminal market growth

Changes in transportation and production technology have been the most significant variables causing changes in the marketing structure of the livestock sector. Before the development of railroads, drovers typically brought livestock to market. Because the distance livestock could be moved on foot was necessarily limited, most livestock was slaughtered in or near production areas.

A few centers of livestock slaughter did develop because of especially advantageous locations with respect to river transportation.

River centers lost their competitive advantage with the introduction of the railroad in the early 1850's. The railroad enabled live animals to be transported great distances and as a consequence great meat packing centers developed. Also spurring the trend toward concentrated meat packing centers was the concentration of hog production in the Northwestern Corn Belt. While production was increasing in

Table 1. Percentage distribution of federally inspected hog slaughter in the Northwestern Corn Belt (years ended June 30) (50, p. 210)

YEAR	NORTHWESTERN CORN BELT[a]
1908	18.8
1909	17.2
1910	17.3
1911	17.7
1912	18.5
1913	18.8
1914	19.3
1915	19.8
1916	19.1
1917	19.0
1918	20.2
1919	20.4
1920	22.1
1921	22.1
1922	21.6
1923	22.9
1924	25.1
1925	27.6
1926	29.6
1927	30.4
1928	28.3
1929	27.8
1930	29.5
1931	31.3
1932	32.4
1933	30.2
1934	29.7

[a]Minnesota, Iowa, Nebraska, North Dakota, South Dakota.

an absolute sense, the Northwestern Corn Belt's proportion of the total was also increasing as shown in Table 1.

Packing centers created the need for exchange mechanisms and therefore the stockyard companies and "producers' representatives" evolved to fill the gap between producer and packer.

The terminal market was born.

The large packing centers did not have the packing field to themselves. Tables 2 and 3 indicate that the per cent of hog slaughter at principal market centers had declined and that receipts at the principal terminal markets in the midwest had begun declining as a per cent of total slaughter in the United States. Yet direct marketing did not become a matter of public controversy until the large terminal market packers began direct buying in the interior (50, p. 4).

2. Direct market development

Direct buying and slaughtering became popular because of: 1) improved roads and truck transportation, 2) freight rate advantages for shipping carcasses over shipping live animals 3) railroad concentration privileges, 4) refrigerated rail cars, 5) increased production specialization in the corn belt, 6) declining volume at terminal yards.

Table 4 shows that truck registrations in Iowa more than doubled between 1920 and 1933 while hog receipts at terminal markets in or near Iowa declined as a per cent of total wholesale slaughter in the U. S. During the same period, the per cent of total U. S. slaughter taking place in the Northwestern Corn Belt increased.

Table 2. Hog slaughter under federal inspection at principal market centers and at all other points, 1908-1934 (50, p. 21)

YEAR	5 NORTHWESTERN CORN BELT STATES[a]	
	Per cent at principal markets[b]	Per cent at all other points
1908	62.8	37.2
1909	63.5	36.5
1910	63.5	36.5
1911	70.0	30.0
1912	68.7	31.3
1913	66.2	33.8
1914	65.0	35.0
1915	62.4	37.6
1916	63.1	36.8
1917	64.2	35.8
1918	65.0	35.0
1919	63.0	37.0
1920	61.0	39.0
1921	59.4	40.6
1922	55.4	44.6
1923	60.6	39.4
1924	58.9	41.1
1925	60.9	39.1
1926	53.0	47.0
1927	49.4	50.6
1928	48.9	51.1
1929	45.2	54.8
1930	47.0	53.0
1931	45.0	55.0
1932	43.2	56.8
1933	40.2	59.8
1934	43.3	56.7

[a]Minnesota, Iowa, North Dakota, South Dakota, Nebraska.

[b]St. Paul, Sioux City, Omaha.

Table 3. Receipts at four principal markets expressed as a per cent of total wholesale slaughter, United States, 1900 through 1933 (50, p. 208)

YEAR	CHICAGO	KANSAS CITY	OMAHA	SIOUX CITY
1900	24.3	9.3	6.6	2.5
1901	23.4	10.5	6.8	2.7
1902	26.3	7.6	7.5	3.4
1903	23.9	6.4	7.3	3.3
1904	21.0	6.5	6.7	3.2
1905	21.1	6.8	6.3	3.5
1906	20.0	7.4	6.6	3.2
1907	19.1	7.7	6.0	3.4
1908	18.3	8.4	5.5	3.1
1909	18.4	8.6	5.9	3.0
1910	18.7	7.0	6.3	3.5
1911	18.1	8.1	6.0	3.4
1912	18.9	6.6	7.6	4.5
1913	19.2	6.5	6.5	3.9
1914	17.6	6.0	6.0	3.3
1915	17.5	5.8	6.0	4.0
1916	18.7	6.1	6.3	4.3
1917	18.8	6.0	7.3	5.6
1918	18.6	7.2	7.4	5.2
1919	18.5	6.7	6.8	5.0
1920	17.7	5.8	6.4	5.1
1921	18.6	5.0	6.1	4.0
1922	16.8	5.5	5.9	3.9
1923	17.5	6.0	6.1	5.0
1924	17.2	4.8	6.6	6.2
1925	16.0	4.1	6.7	6.8
1926	15.7	4.5	5.9	5.5
1927	16.0	3.9	5.4	4.8
1928	15.3	4.3	5.7	4.9
1929	15.0	4.5	5.8	4.2
1930	15.5	4.0	6.6	4.6
1931	15.6	2.6	6.9	5.2
1932	13.1	2.7	6.1	3.9
1933	13.3	3.6	5.1	3.9

Table 4. Motor truck registrations (in thousands) in Iowa, the Northwestern Corn Belt and the United States, 1920-1933 (50, p. 212)

YEAR	IOWA	NORTHWESTERN CORN BELT	UNITED STATES
1920	30	83	1,003
1921	31	84	1,119
1922	31	105	1,376
1923	36	126	1,613
1924	41	126	2,133
1925	46	153	2,442
1926	51	177	2,764
1927	55	201	2,914
1928	61	226	3,114
1929	70	261	3,380
1930	72	292	3,486
1931	78	297	3,466
1932	74	247	3,233
1933	69	270	3,227

The Direct Marketing of Hogs (50, p. 79) documented the second reason for the move toward direct buying and slaughter:

> In general, on all shipments originating at points in the Corn Belt States and moving eastward, freight rates per 100 pounds on hogs are higher than the freight charge on hog products obtained from 100 pounds of hog. This is especially true for points located between the Missouri and Mississippi Rivers.

Railroad concentration privileges were a third reason for bypassing terminals. One of the common concentration privileges granted was allowing livestock to be stopped at an intermediate point for not longer than one year for feeding and fattening, while paying only the through rate from first origin to final destination. The advantage lies in the fact that the through rate was generally less than the combination of two local rates.

Packers at terminal markets could thus operate interior buying points for hogs and benefit from the lower rates. Hogs could be stopped, sorted and sold and then sent to packing plants at the weights desired. Thus, sorting and exchange functions generally performed at terminal markets were being completed at interior points and there was less need for the hogs to move through terminal yards.

Of course none of the move to interior slaughter would have been possible without refrigerated rail transportation for fresh pork. Also, high density production made it possible for plants to secure large supplies within a small geographic area.

The trend toward direct marketing has continued. Table 5 shows that by 1940 only 20 per cent of Iowa slaughter hogs were sold through terminal markets and less than 40 per cent of the slaughter hogs from 14 North Central states were sold through terminals.

The 1961 to 1969 figures in Table 6 are even more impressive. Less than 20 per cent of the hogs purchased by packers in 1969 were purchased through terminal markets in the U.S. Iowa packers purchased less than 13 per cent of their slaughter through terminals.

The reasons for bypassing the terminal are obvious. In Iowa there are over 1200 interior buying locations. Figure 1 shows the location of 228 salaried packer buyers and 22 packing plants. Figures 2 and 3 show the location of 139 auction markets and 832 registered dealers and order buyers.

Indications are that the terminals will lose even more of their volume in the future

> since younger and larger producers...tend to by-pass terminals and auctions over time slaughter receipts at these facilities will continue to decline. This decline is due partly because the exit of older producers from agriculture or livestock feeding and a continual increase in size of livestock operation, larger producers also tend to by-pass terminal and auction markets (39, p. 63).

Changes in production density cannot be neglected as a cause of the current market trend.

> The implications for slaughter firms seem clear. Specialization of production points to increasing marketing within the Corn Belt and decreasing marketings outside the Corn Belt. This will likely mean that firms will expand, or new firms will enter, to handle the increased marketing... (10, p. 4).

All of these structural changes have caused or have been caused by producers adjusting marketing procedures. The adjustments have not been easy nor rapid and quite often producers and other marketing agents openly protest the marketing system's changes.

For example, three producers' arguments against direct buying were:

1. Direct packer buying at interior country points

Table 5. Per cent of slaughter hogs sold by farmers at various types of markets, 1940 (29, p. 125)

	IOWA	CORN BELT
Terminal Public Markets	20.2	37.8
Packing Plants	32.3	22.3
Dealers	24.4	12.9
Auctions	1.3	5.0
Concentration Yards or Local Markets	15.4	15.4
Cooperative Associations	6.0	5.6
Farmers and Others	0.4	1.0
Total	100.0	100.0
No. Farmers Reporting	1,231	23,703

takes the cream of the crop and therefore the base prices in Chicago do not accurately reflect quality grades.

2. There is no competition.
3. Country buying by terminally located packers reduces competition and prices at the terminal (38, p. 187).

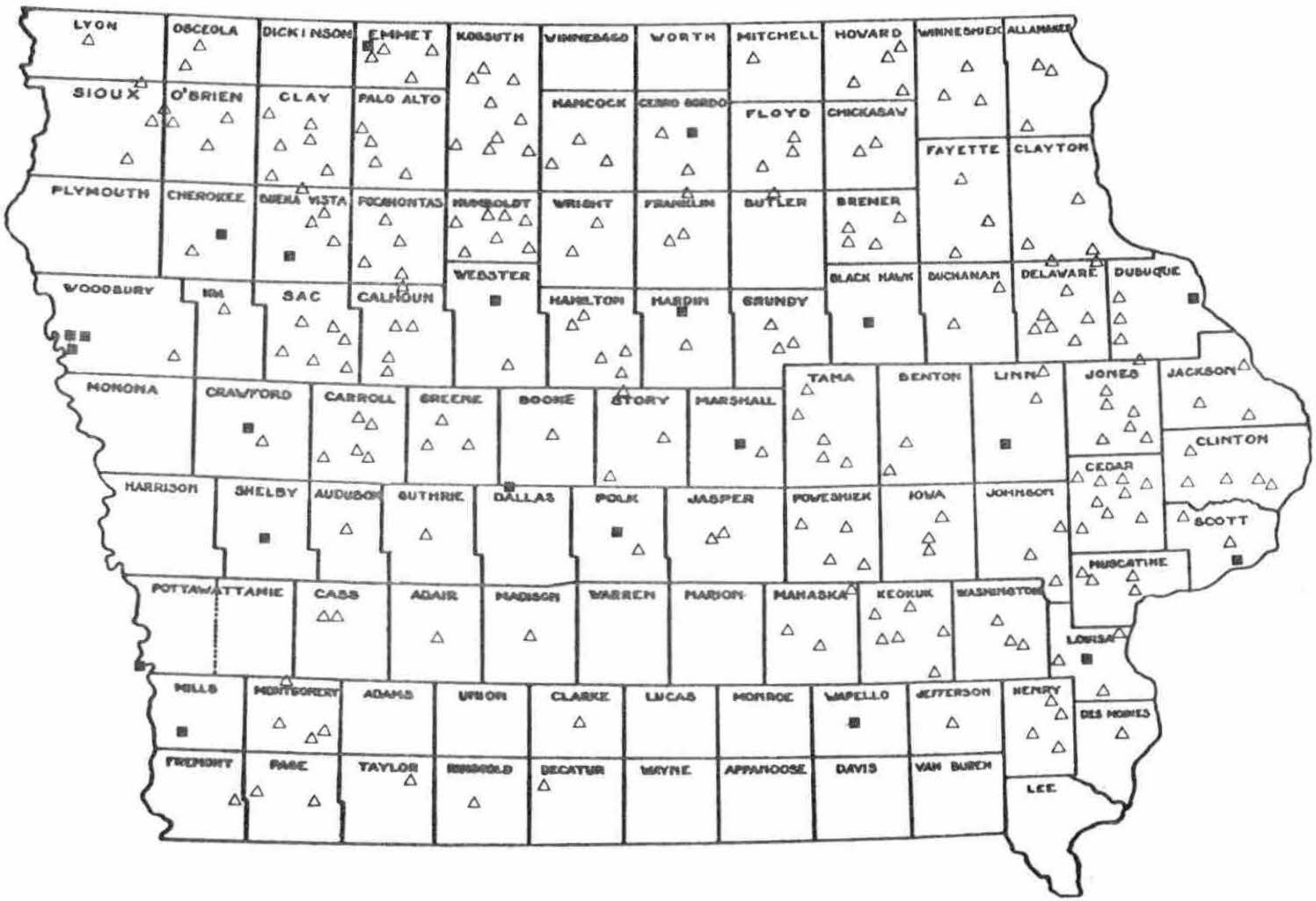

Figure 1. Location of 228 packer owned buying stations and 22 large hog slaughter plants in Iowa. Key: △ packer owned buying stations; ■ slaughter plants. Data were collected from a survey of packers in Iowa

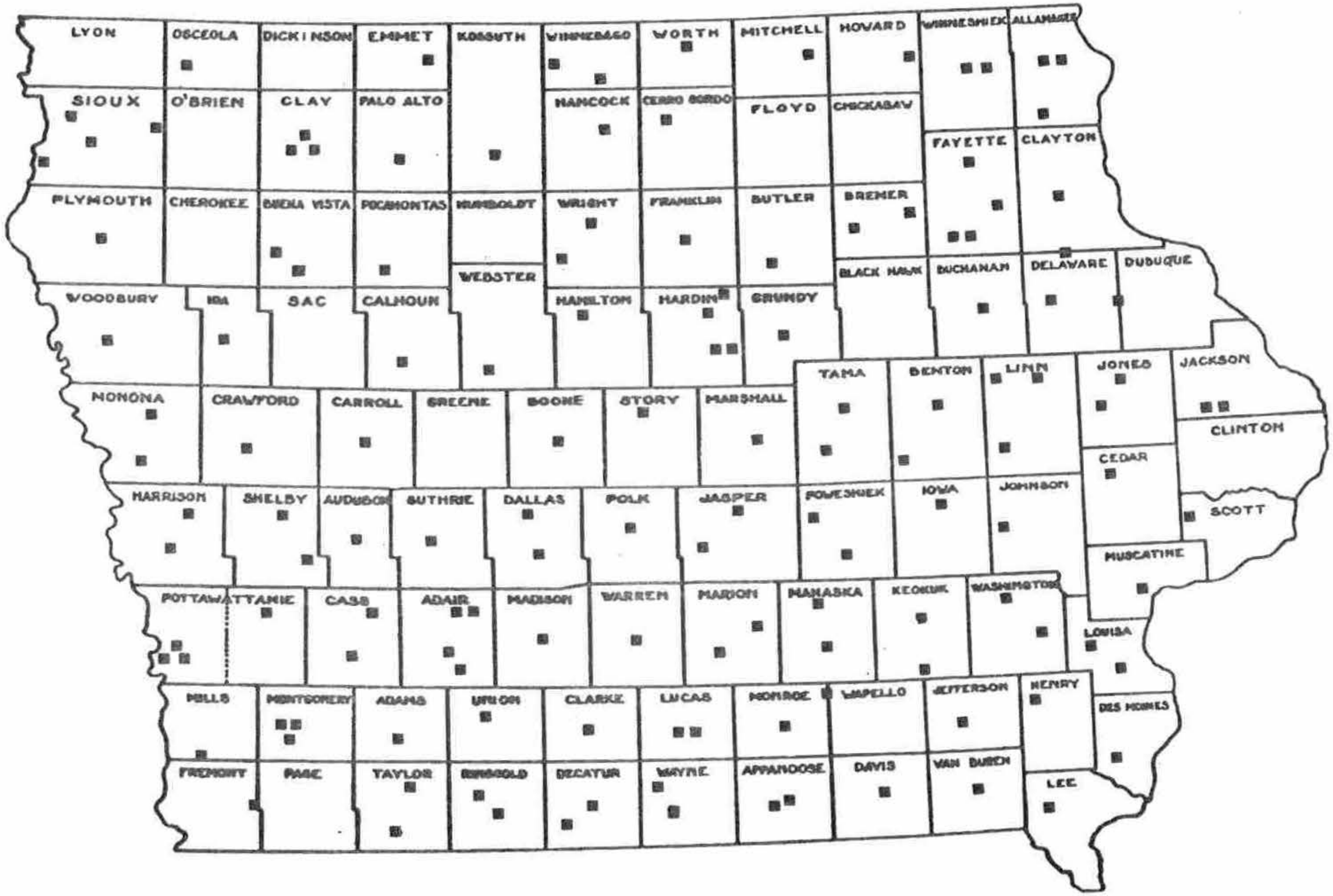

Figure 2. Livestock auction market locations in Iowa (1)

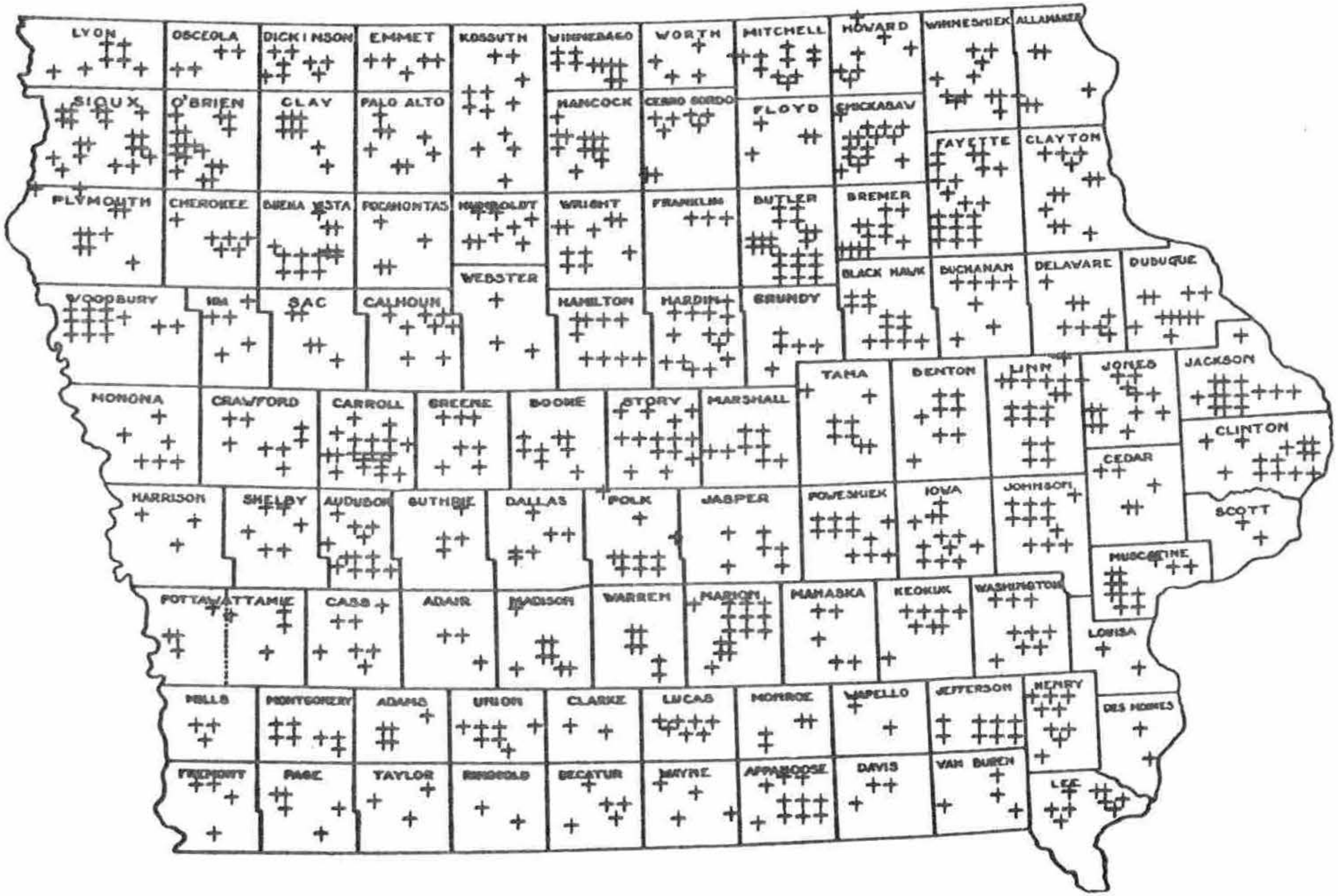

Figure 3. Registered dealers and order buyers in Iowa (1)

Table 6. Packer purchases of hogs in the United States (49, p. 8)

YEAR	DIRECT, COUNTRY DEALERS, ETC. (per cent)	TERMINALS (per cent)	AUCTIONS (per cent)
1961	59.6	29.2	11.2
1962	59.6	29.3	11.1
1963	60.7	26.6	12.7
1964	63.1	23.8	13.1
1965	62.9	23.4	13.7
1966	62.7	22.1	15.2
1967	65.7	18.8	15.5
1968	66.6	19.3	14.1
1969	67.4	18.9	13.7
1970	68.5	17.1	14.3

In 1935, the USDA's Agricultural Economics Bureau concluded that most of the criticisms were unfounded:

> Direct marketing has not lowered the general level of hog prices, nor has it operated to reduce returns to producers...There are not fixed price differences between public markets and interior points ...Direct marketing has not increased marketing costs nor widened the margins...nor has it deprived public markets of supplies of the various qualities ...In general, the study showed that direct marketing has not operated to the disadvantage of hog producers (50, p. 2).

More recently, the close of Chicago's Union Stockyards created much controversy (32). Arguments by producers and marketing agents against the closing received widespread publicity.

Claims that producer marketing power is being reduced and a desire to combat the trend has been the main theme emphasized by the National Farmer's Organization.

3. The future marketing system

Despite the conflict, structural changes continue. For example, one particular packer has revolutionized his procurement system:

> 1. They coordinate the buying activities of 62 feedlot buyers who operate in over 100,000 square miles of beef-supply territory located in more than five states. A micro-wave car radio-telephone communications system links the mobile country buyers with headquarters, providing close control of maximum prices paid. Records are kept of each lot that is bought...Each buyer is compared with other buyers. Through salaries and commissions, buyers are rewarded according to their relative efficiency.
>
> 2. They direct the flow of live cattle to one of their six country slaughtering plants...(2, p. 87).

Similar connections exist on the wholesale meat side of the operation. What is significant is that live cattle move from farm to slaughter with limited unloading and time spent. The producer is not required to leave his farm in order to receive a bid on his cattle. Also, the traditional marketing channels have been bypassed. Other types of vertical integration and coordination include farm contracting and feedlot operations built by grocery store chains.

The Ontario and Alberta, Canada hog marketing systems are another example of using technological hardware advances in an attempt to create a better marketing structure (27).

In Iowa, changes are rapidly taking place at the production level.

From Table 7, we find that the number of farms reporting farrowings has remained almost constant. This means that a greater percentage of sows are being farrowed in larger groups and in Table 8 we see that producers in 1970 marketed more hogs per farm than were marketed in 1968 or 1969.

The marketing structure for farm products is continuing to change and adapt to new technology and different cost situations in the industry.

B. Purpose, Hypotheses and Benefits

The purpose of this study was to predict on strictly economic grounds a structural change in the market for live slaughter hogs.

Specifically, an analysis of the market structure implications of an increase in the number of hogs being shipped directly to plants was made. Producers increased direct plant sales because:

1. More services such as grade and yield buying are offered at plants.
2. Larger lot sizes can be moved in larger trucks that make it worthwhile to ship longer distances.
3. Packers pay a premium for plant deliveries.

The factors influencing producers' selling decisions are often more subtle than those above, but the list is not meant to be exhaustive.

Two basic hypotheses were tested:

1. Fewer larger buying stations could move hogs to

Table 7. Farms reporting spring sow farrowings: total number reported and number reported by herd size groups as a per cent of the total number of spring sow farrowings in Iowa, December 1 to June 1, 1964-1971 (47)

YEAR	FARMS REPORTING SPRING SOW FARROWINGS	TOTAL SPRING SOW FARROWINGS	SPRING SOW FARROWINGS BY SIZE GROUPS AS A PER CENT OF TOTAL					
			1-10 sows	11-20 sows	21-30 sows	31-50 sows	51 sows or more	Total
1964	77,795	1,459,498	11.0	36.1	24.7	18.9	9.3	100.0
1965	71,593	1,379,570	10.5	34.6	24.3	20.0	10.6	100.0
1966	71,193	1,458,353	8.9	31.2	25.0	21.9	13.0	100.0
1967	68,959	1,439,890	8.6	30.9	24.7	22.3	13.5	100.0
1968	65,000	1,380,202	7.9	29.7	24.4	23.5	14.5	100.0
1969	58,969	1,322,603	7.2	28.3	24.4	23.9	16.2	100.0
1970	58,638	1,417,829	6.0	24.8	23.5	25.9	19.8	100.0
1971	55,898	1,333,086	6.6	25.4	22.7	24.8	20.5	100.0

Table 8. Farms marketing hogs: total number and per cent by marketing size groups in Iowa, 1968-1970 (47)

YEAR	NUMBER OF FARMS REPORTING	FARMS REPORTING HOGS MARKETED BY SIZE GROUPS AS A PER CENT OF TOTAL						
		Under 100 hogs	100-199 hogs	200-349 hogs	350-499 hogs	500-999 hogs	1000 or more hogs	Total
1968	72,811	26.3	25.8	26.5	10.6	9.3	1.5	100.0
1969	70,677	26.6	24.9	26.2	10.8	9.9	1.6	100.0
1970	69,034	25.0	23.6	26.2	11.6	11.5	2.1	100.0

market at a lower cost than the current system.

2. The operationally efficient number and size of transhipment points depends on lot size and production density.

The following implications of the results will be discussed:

1. What are some of the barriers to making structural adjustments?
2. What will be the nature of the competitive atmosphere if the adjustment is made?
3. Which type or types of transhipment points will facilitate minimum cost flows?

Several groups should benefit from knowing the answers to the above questions.

Producers would be able to adjust more easily to the structural change if the change was predicted.

Packers should be able to make wiser long range planning decisions with respect to the nature of their future procurement operations. Should buying stations be repaired or rebuilt? Should new buyers be trained and hired for country points?

Consumers should benefit if some of the savings gained by applying additional knowledge is passed on through the marketing channel.

And finally, policy makers should view the results to determine whether a remodeled marketing structure unduly shifts the balance of power in the market place. Are legal restrictions going to be necessary in order to achieve some of their farm policy goals?

II. LITERATURE REVIEW

Two recent publications concerned with slaughter hog marketing in the Midwest are reviewed in this chapter. The two publications were selected because they represent classic applications of two fundamental techniques used to determine the cost-output relationship for firms.

A Comparative Cost Analysis of Alternative Marketing Systems for Slaughter Hogs in Michigan (41) by James G. Snell is an application of the economic-engineering approach to measuring costs and outputs of marketing agencies.

In contrast, the Operational Efficiency of Illinois Country Hog Markets (2) by Emer E. Broadbent and Steve R. Perkinson relied on the accounting data to measure costs and outputs of marketing agencies.

Snell's work is more complete because marketing costs from farm gate to slaughter house door are considered and several alternative marketing channels are hypothesized. The Broadbent-Perkinson study is concerned with the costs of only one stage in the marketing channel.

A. Operational Efficiency of Illinois Country Hog Markets

The Broadbent-Perkinson report is divided into two parts. Part one is largely the author's speculation about how the marketing system will change as indicated by the results of their study. Part two is a report on the data collected, variables used and considered and the regression estimation of the cost-volume relationship.

Data was obtained from the cost records of 30 country order-buying points and 18 packer buying points. Transportation, shrinkage and overhead costs were not included.

1. Part I

Part one is an exposition of what the authors were thinking rather than what they had proven. It does not seem that their research supports their thoughts well enough for them to be stated as fact. Perhaps to someone familiar with Illinois slaughter hog markets, part one reads as a report of facts and conclusions previously supported by other research.

The opening two paragraphs are prime examples:

> The demise of terminal marketing operations has overlapped with the proliferation of country markets where order-buyers, packer-buyers, and dealers buy and sell livestock. However, these country points are costly to establish and maintain; also, most of the operators are not receiving enough income in service and packer-commission fees to cover the operating costs involved. Hence, the duplication of high-cost country markets can only be an interim phase in the evolution of an integrated livestock-marketing system. The need for local markets to perform the assembly, sorting, and standardization functions is not as essential today when Illinois has fewer than 65 thousand hog producers as in 1939 when the number was over 132 thousand.
>
> The present, high-cost, country-point marketing system will be supplanted eventually by one in which more sophisticated marketing firms will represent the large-volume operators, selling livestock directly from the feedlot. Ultimately, the market flow could be programmed for specific delivery dates at the time the sows are bred or when the feeder cattle go into the feedlot. Along with this will come a greater use of weight, grade, and

> shrinkage standards that are more nearly uniform and acceptable to all the parties concerned (2, p. 1).

Even though "most of the (country point) operators are not receiving enough income in service and commission fees to cover operating costs involved" (2, p. 1) it is not certain that country operators are not providing a service and certainly many if not most of them are making a profit from their hog buying enterprise.

As stated later in part one, country order buying points can earn income by paying producers a smaller price than they are paid by packers. Packers may be willing to pay country point operators a higher price because of contractual agreements, or because country points provide larger more uniform loads.

Packer-owned buying stations can help pay their own way by providing a buffer stock of slaughter animals so that plants can be sure of continuous supply. Although the Broadbent-Perkinson report alludes to a system that will provide a "programmed flow" at specific delivery dates, they do not recognize the ability of the current buying station system in providing a "programmed flow."

Even more important, the Broadbent-Perkinson study did not estimate the full cost of the current system and certainly provided no estimates of the costs of operating "sophisticated marketing firms" in the future system. Until the costs involved are evaluated and compared to the current system's costs it is impossible to prove or rebuff the conclusions stated by Broadbent and Perkinson.

The conclusions about how the system will change were unwarranted because their study evaluated only one stage in the system. Transportation costs were ignored and are probably as important or more important than country market operating costs.

Other economies external to the buying stations that accrue to the system because of steady flows to packing plants are harder to evaluate in cash terms but are also part of the benefits that would need to be evaluated prior to stating conclusions about the changing marketing system.

2. Part II

Part II is a report on identifying the significant factors that explain country buying point per-head cost variation. Least-squares multiple regression was used to estimate the relationship between per-head cost and "principal cost determining variables."

The results of the research provide an important set of data useful to researchers using a systems approach to the slaughter hog marketing problem.

The three variables found significant were: volume of receipts, rate of market facility use and replacement value of land and facilities per hog handled. The .893 r-squared indicates that approximately 89 per cent of the variation in

Table 9. Efficiency factors considered for four groups of Illinois country markets, 48 in all, 1965 (2, p. 9)

Volume	Unit cost: Total	Unit cost: Labor	Per cent of capacity utilized	Weekly volume per employee
		Group 1		
12,915	$0.93	$0.59	78	248
14,730	.82	.51	75	283
15,110	.95	.60	85	291
15,952	.73	.42	73	307
16,245	.72	.46	81	312
16,269	.92	.43	56	313
16,558	.73	.44	70	318
16,996	.96	.54	81	164
17,169	.82	.46	67	330
17,510	.68	.38	56	337
18,214	.67	.42	69	350
18,265	.82	.46	99	176
Average 16,328	$0.81	$0.47	..	269
		Group 2		
18,332	$0.72	$0.46	86	353
18,521	.63	.40	77	356
19,544	.92	.37	65	376
21,811	.63	.40	80	419
21,933	.47	.30	68	422
23,179	.78	.47	69	223
24,454	.63	.34	88	470
28,530	.66	.30	76	549
29,190	.70	.35	80	280
29,214	.55	.34	68	562
29,632	.64	.33	85	356
30,247	.54	.30	72	466
Average 24,549	$0.65	$0.36	..	381

Table 9 (continued)

Volume	Unit cost Total	Unit cost Labor	Per cent of capacity utilized	Weekly volume per employee
	Group 3			
30,411	$0.47	$0.24	60	585
30,417	.60	.32	78	292
31,039	.70	.28	69	398
32,617	.54	.29	98	299
33,089	.54	.34	51	318
34,130	.62	.36	77	656
34,744	.55	.32	78	334
36,810	.38	.19	88	708
37,215	.67	.34	89	358
37,313	.54	.22	91	359
38,437	.36	.19	80	739
45,234	.44	.21	78	580
Average 35,121	$0.53	$0.27	..	424
	Group 4			
55,136	$0.55	$0.23	97	530
55,279	.44	.26	69	532
55,598	.42	.20	48	713
56,417	.33	.19	89	542
57,241	.56	.25	96	550
62,997	.53	.26	80	404
73,133	.54	.32	70	469
91,927	.51	.29	99	737
102,691	.43	.21	63	988
108,500	.37	.15	77	1391
118,271	.35	.20	90	1137
127,813	.32	.15	93	1238
Average 80,417	$0.43	$0.22	..	731

Table 10. Replacement value of market facilities and land per hog marketed, four groups of Illinois country markets, 48 in all, 1965 (2, p. 10)

	Replacement value	Annual volume	Replacement value per hog
		Group 1	
	$13,000	12,915	$1.01
	11,500	14,750	.78
	18,000	15,110	1.19
	11,500	15,952	.72
	17,500	16,245	1.08
	16,000	16,269	.98
	30,000	16,558	1.81
	40,000	16,996	2.35
	8,000	17,169	.47
	35,000	17,510	2.00
	18,000	18,214	.99
	9,200	18,265	.55
Average	$18,975	16,328	$1.16
		Group 2	
	$10,000	18,332	$ .55
	9,000	18,521	.49
	36,000	19,544	1.84
	8,000	21,811	.37
	14,800	21,933	.67
	50,000	23,179	2.16
	12,500	24,454	.51
	30,000	28,530	1.05
	21,000	29,190	.72
	40,000	29,214	1.37
	23,000	29,632	.78
	7,500	30,247	.25
Average	$21,817	24,549	$ .89

Table 10 (continued)

	Replacement value	Annual volume	Replacement value per hog
		Group 3	
	$ 8,500	30,411	$ .28
	17,500	30,417	.58
	30,000	31,039	.70
	26,500	32,039	.81
	19,500	33,089	.59
	17,500	34,130	.51
	22,000	34,744	.63
	17,000	36,810	.46
	30,000	37,215	.81
	30,000	37,313	.80
	20,500	38,437	.53
	24,000	45,234	.53
Average	$21,917	35,121	$ .62
		Group 4	
	$ 35,000	55,136	$ .63
	14,500	55,279	.26
	30,000	55,598	.54
	22,000	56,417	.39
	30,000	56,241	.52
	30,000	62,997	.48
	115,000	73,133	1.57
	21,000	91,927	.23
	20,000	102,691	.19
	23,000	108,500	.21
	32,000	118,271	.27
	34,000	127,813	.27
Average	$33,917	80,417	.42
AVERAGE, ALL MARKETS	$24,156	39,104	$ .62

per-head cost can be associated with variation in the three independent variables.

No explanation of how the three variables were selected from a somewhat larger set was given. The regression equation reported was:

$$(1)\quad \log Y = 4.7793 - .3851 \log X_1 + .6720 \log X_2 + .1021 \log X_3$$

where Y = cost per hog handled

X_1 = volume of receipts in thousands of hogs

X_2 = rate of market facility utilization and

X_3 = replacement value of land and facilities per hog handled.

Using the data provided in appendix Tables 2 and 3 (2, p. 9-10) it was not possible to duplicate the results using both base 10 logarithms and base e (natural) logarithms. The Broadbent-Perkinson data is duplicated in Tables 9 and 10. Total unit cost, volume and per cent of capacity utilized columns of Table 9 were used for Y, X_1, and X_2 respectively. Replacement value of land and facilities per hog from Table 10 was used as X_3.

Table 11 summarizes the Broadbent-Perkinson results and then attempts to duplicate their model. The model used is the same as the one published in the Broadbent-Perkinson report and has been stated previously.

Table 11. Comparison of regression results

Variable	Coefficient value	Standard error	t value
BROADBENT-PERKINSON RESULTS[1]			
Intercept	4.7793		
log X_1	-0.3581	0.047	-8.2*
log X_2	0.6720	0.086	7.8*
log X_3	0.1021	0.050	2.0**
	$s^2 = 0.030$		
	$r^2 = 0.893$		
USING APPENDIX DATA AND BASE 10 LOGARITHMS			
Intercept	0.9672	0.3273	2.95*
log X_1	-0.3181	0.0497	-6.39*
log X_2	0.1375	0.1440	0.96
log X_3	0.1236	0.0480	2.57**
	$s^2 = 0.005$		
	$r^2 = 0.7086$		
USING APPENDIX DATA AND BASE e LOGARITHMS			
Intercept	2.2270	0.3273	2.95*
ln X_1	-0.3181	0.0497	-6.39*
ln X_2	0.1375	0.1440	0.96
ln X_3	0.1236	0.0480	2.57**
	$s^2 = 0.027$		
	$r^2 = 0.7086$		

[1]Source (2, p. 7)

*Significant at 99 per cent level

**Significant at 95 per cent level

The absence of a significant t value for X_2 in the duplicate regressions was the greatest discrepancy between the results. Further analysis of the Broadbent-Perkinson data is reported and used in Chapter 4.

B. A Comparative Cost Analysis of Alternative Marketing Systems for Slaughter Hogs in Michigan

A Comparative Cost Analysis of Alternative Marketing Systems for Slaughter Hogs in Michigan by James G. Snell (41) represents an application of the economic-engineering cost analysis procedure. The economic-engineering approach was well outlined by French, Sammet and Bressler (11).

What is more important is the systems approach that allows evaluation of the costs of hog marketing from farm gate to slaughter house door. The four systems analyzed were: a synthetic present system, a large auction system, a large local market system and a direct marketing system. Costs for each system were analyzed under three sets of assumptions: (1) structural changes in the slaughtering and production stages of the industry, (2) seasonal and stable supply conditions and (3) five levels of total hog production.

The strongest point of Snell's thesis was the five alternative sets of exogenous conditions he specified.

The economic-engineering approach can be faulted because of the hypothetical nature of the cost functions derived. When accounting records are consulted, one can say that a firm produced a certain quantity and incurred the following costs. With the economic-engineering approach, the firm's cost function is not empirically verifiable. The synthesized firm need not exist and in some cases it is said to be the optimal firm organization.

On the other hand, the economic-engineering approach does allow a great deal of flexibility in the number of and type of firms that can be hypothesized.

The comparative systems approach used by Snell is not an optimization process. All that can be said is that the systems evaluated had the following costs. However, the systems approach does allow the tradeoff between individual firm efficiency (micro efficiency in Snell's terminology) and system efficiency (macro efficiency). Snell's general conclusion that

> The macro efficiency of a marketing system depends not only on the micro efficiency of the individual market participants but also upon (1) the production density, (2) the type of transportation cost function and (3) the packer location pattern relative to the production pattern (41, p. 167).

reflects the nature of the systems approach. Making rather brash statements about the efficiency of individual stages in the system does not definitely say that the system as a whole is not macro efficient. A macro efficient system may require some firms operating inefficiently (micro inefficiency). Snell describes micro efficiency as when a firm is operating at the minimum point of its long-run average cost curve.

Similarly, the system is considered macro-efficient if the system is operating at the minimum point of its long-run average cost curve. Macro and micro efficiency may not be compatible.

The primary advantage of the systems approach is the number of solutions that can be completed. The systems approach is not an optimization procedure and thus is generally less expensive per solution. Therefore, under a given budget constraint the costs of the market can be estimated with several sets of assumed exogenous conditions. Using an optimization procedure the same budget constraint would probably not allow the researcher to specify as many sets of exogenous conditions.

Snell's approach and data were far from perfect however.

Although Snell's model was flexible because of the number of exogenous conditions that were specified, it was inflexible in several other respects.

For example, he assumed that given a certain number of a given type of agency, all hogs going to a particular type of agency went to the nearest available agency of that type. In other words, "the implicit assumption is that there is competition between channels, but not between firms within a channel (41, p. 72)."

Secondly, the transportation rates used seem highly suspect. Snell divided Michigan into rotated square market areas for several of his models. Average producer transportation costs for given sized marketing areas were determined by using the following procedure:

> ..., the marketing area with a maximum shipping distance of 30 miles had 69 per cent of its total within range of 25 miles. Therefore, the average transportation rate for that market area was the 25 mile rate times .69, the 50 mile rate times .31 or the per cent of the total area beyond the 25 mile distance (41, pp. 73-76).

Granting that transportation cost functions are often step functions, tariffs in Iowa have much shorter distance steps (see Table 29). A telephone survey of truckers seemed a very lazy way of obtaining rate information. Also, it seemed likely that producers with five and 15-head lots would often ship them in their own pickup truck in which case the costs could be considered a continuous function with respect to distance. Also, truck charges do not make up the total transportation bill. Producers generally travel to markets and incur costs that increase as distance increases. These costs are not included in Snell's study and should have been. Because these costs are constant with respect to lot size, the relative cost per head would change for the different lot sizes. Also, because of the oversight, the cost of direct marketing may have been understated.

In general, although Snell concludes that the efficiency of a marketing system depends on the type of transportation function assumed, it seems as though he spent little time thinking about the producer's true cost of hauling hogs and did not use a realistic rate schedule.

Much of the rest of Snell's report relies on stage cost and time requirements derived by Gibb (13). Snell can be faulted because his estimates of the local market stage costs were assumed to be the same as activity costs found in a study of auctions reported by Gibb. Snell generated little of the hard information that you usually expect from an economic-engineering cost study. Where new information was deemed necessary, Snell often refers to "interviews with packers" (41, p. 107) or "interviews with industry personnel" (41, p. 109). In this respect, Snell's work is very meager although it is often difficult to find and measure all the costs associated with the marketing activity.

C. Summary

Both the Broadbent-Perkinson and Snell studies reached similar conclusions that a direct integrated marketing system would be least expensive or most efficient. The reliability of their conclusions was questioned--in the first case because the system was not analyzed and in the second case because transportation costs were handled poorly.

III. MODEL DEVELOPMENT

The purpose of this chapter is to outline some of the historic models and theories that preceded the development of King and Logan's (22) transhipment, optimum location, number and size of processing plant model to be applied to slaughter hog marketing in Iowa.

Section A states the classic transportation model and its assumptions. Section B gives Stollsteimer's (43) plant numbers and location model. Section C explains transhipment and compares it to transportation models, and Section D formally states the King and Logan (22)[1] model to be used in this study. Hopefully, Section D also shows the relationship between the preceding three sections and the King and Logan model.

Should the reader feel he understands the above topics, he would be well-advised to skip Chapter III. The chapter is primarily written in non-technical language. Someone who has been introduced to linear programming should be able to conceptualize the King and Logan model's mechanism upon completion of this section. Although mathematical notation is given, Chapter III is not intended to be a full technical presentation.

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[1]The model to be explained in this section which will be referred to as the "King and Logan" model first appeared in a journal as Reference 22. However, the model presented in Reference 22 was taken from an unpublished paper by George Judge (20). The astute reader will recognize the similarities between the techniques to be used in this study and the spatial equilibrium model solution techniques presented by Judge (20).

Perhaps Chapter III can best be described as explanation by analogy. Section A reviews the classic transportation model and Section B shows how the transportation problem was adapted by J. F. Stollsteimer in a plant location model. Section C shows the difference between transportation and transhipment problems and Section D describes how transhipment has been incorporated into plant location models by King and Logan.

The analogy between transportation-plant-location models and transhipment-plant-location models should help the reader understand how the latter works by comparing it with the previous description of the transportation-plant-location model.

A. The Classic Transportation Problem

The transportation problem to be presented is described by Dantzig (5) as the classic problem because of its basic assumptions. The discussion that follows is largely a statement of the Hitchcock (17) and Koopmans and Reiter (23) formulation.

1. Objective function

The transportation problem objective is: given M sources of a good and N destinations, what is the routing pattern of good X from source to destination that minimizes total transportation costs. Stated mathetically, the objective is to minimize:

$$(2) \quad \sum_{m=1}^{M} \sum_{n=1}^{N} C_{mn} X_{mn}$$

where X_{mn} represents a physical quantity shipped from source m to destination n, C_{mn} represents the cost of moving one unit from m to n, and where m = 1,2,3,...M sources and n = 1,2,3, ...N destinations.

2. Assumptions

The transportation model's six assumptions are:

1. The sum of what leaves every source is equal to the quantity produced by that source.

$$(3) \quad \sum_{n=1}^{N} X_{mn} = a_m \qquad m = 1,2,3,\ldots M$$

2. The sum of what arrives at each destination is equal to the demand at that destination.

$$(4) \quad \sum_{m=1}^{M} X_{mn} = b_n \qquad n = 1,2,3,\ldots N$$

3. Negative shipment activities are not allowed. Shipments cannot take place from n to m. This assumption is necessary because the costs of moving from n to m are not necessarily the same as the costs of moving from m to n.

$$(5) \quad X_{mn} \geq 0$$

4. The sum of what is supplied by the sources is equal to the sum of what is required by the destinations. Mathematically, this is simply shown by summing Equations (3) and (4) over m and n respectively, resulting in:

$$(6)\quad \sum_{m=1}^{M} \sum_{n=1}^{N} X_{mn} = \sum_{m=1}^{M} a_m$$

$$(7)\quad \sum_{n=1}^{N} \sum_{m=1}^{M} X_{mn} = \sum_{n=1}^{N} b_n$$

Because the order of summation of the X_{mn} is irrelevant, it is concluded that the sum of what is supplied by the sources is equal to the sum of what is required by the destinations.

$$(8)\quad \sum_{m=1}^{M} a_m = \sum_{n=1}^{N} b_n$$

5. The absence of weights in Equation 2 means that it is assumed the good is homogeneous.
6. The cost of moving units from origins to destinations is independent of the quantity shipped. (The objective function is linear.)

3. Reformulation

Operationally, transportation problems are formulated so that Equation 8 is formally met but may not actually be true. Over or under supply is allowed for by introducing dummy sources or destinations so that Equation 8 holds and the problem can be solved even though the total number of units desired does not equal the total number of units supplied. Also, when operationalizing transportation models, the transfer costs from m to n are assumed to be known or available and sources and destinations are represented by a point.

B. Transportation-Optimum Location:

The Stollsteimer Approach

Perhaps the best and most widely quoted plant numbers, size and location study was done by J. F. Stollsteimer (43). Because of its many empirical applications, the model will be used as the basis for this section.

The Stollsteimer model

> ...considers the problem of simultaneously determining the number, size and location of plants that minimize the combined transportation and processing costs involved in assembling and processing any given quantity of raw material produced in varying amounts at scattered production points (43, pp. 631-632).

In other words

> Given I raw material sites, each of which produces a quantity X_m of a material to be assembled and processed at one of L possible locations, the problem is one of determining the number, size and location of facilities that will minimize the combined cost of assembling and processing the total quantity of raw material produced in the region (42, p. 632).

The following notation will be used:

TC = total processing and assembly cost

a_m = quantity available from the ith origin, m = 1,2,3,...M

P_n = unit processing costs in plant n located at L_n, n = 1,2,3,...N

b_n = quantity desired by the jth plant, n = 1,2,3,...N

X_{mn} = quantity of raw material shipped from origin m to plant n located at L_n

C_{mn} = unit cost shipping material from origin m to plant n located with respect to L_n

L_k = one locational pattern for N plants among the $\binom{L}{N}$ possible combinations of locations for N plants given L possible locations

L_n = a specific location for an individual plant, $n = 1,2,3,\ldots N$

The Stollsteimer problem's objective function is to minimize:

$$(9) \quad TC = \sum_{m=1}^{M} P_m X_m \Big| L_k + \sum_{m=1}^{M} \sum_{n=1}^{N} X_{mn} C_{mn} \Big| L_k$$

with respect to plant numbers (N) and locational pattern $L_k = 1,2,3,\ldots\binom{L}{N}$ subject to the following restrictions:

$$(10) \quad \sum_{n=1}^{N} X_{mn} = a_m,\ m = 1,2,3,\ldots M$$

The quantity shipped from the ith origin is equal to the amount available from that origin.

$$(11) \quad \sum_{m=1}^{M} X_{mn} = b_n,\ n = 1,2,3,\ldots N$$

The quantity received by n is equal to the quantity of material processed at plant n per production period.

$$(12) \quad \sum_{n=1}^{N} \sum_{m=1}^{M} X_{mn} = X$$

The total quantity shipped is equal to the total quantity of raw material produced and processed.

$$(13) \quad X_{mn},\ X_n \geq 0 \quad C_{mn} \geq 0$$

All shipments, processing volumes and costs must be greater than or equal to zero.

At this point a non-mathematical interpretation of Equation 9 is in order. The first term to the right of the equality represents total processing cost. It is the sum over all plants of the quantity processed at each plant (X_n) multiplied by the cost of processing (P_n) at each particular plant given a particular location pattern (L_k) of N plants.

The second term to the right of the equality is the already familiar transportation cost minimization objective function except that the number of destinations (N) and their locations (L) are variable.

Equivalent equations to 10, 11, 12, and 13 were also found in the classic transportation model presented in Section A.

In sum, the Stollsteimer model is the same as the transportation model with two important changes. The processing cost function is added to the objective function and the number and location of destinations are variables and left to be determined in the model.

Minimizing Equation 9 is done in two parts: transportation and production. First, the minimum transportation cost function is derived and then the relationship determining production costs is developed.

In order to determine the minimum transportation cost function, it is necessary to know the least-cost locational pattern (L_k) for varying numbers (N) of plants. The question to be answered is: of the various locational patterns of N plants, which pattern minimizes transportation costs (where N = 1,2,3,...L).

Theoretically, the procedure is to first choose which one plant location minimizes total transportation costs, then which combination of two plants minimizes total transportation costs and so on until all L possible plant locations are included and the transportation cost function is at its minimum.

In practice with problems of any great size this is not done because the time and money is not available. With just 10 potential locations, the number of transportation models that would have to be solved for each of the N number of plants is shown in Table 12.

Thus, two suboptimization approaches to the problem have been illucidated by Warrack and Fletcher (54).

The first has been named the iterative elimination approach, IELMA. This approach begins with all plants in the solution and then asks: "Will the elimination of any plant from the trial solution reduce the value of the objective function?" If yes, the plant whose elimination reduces the objective function value the most is removed. This process continues until the removal of any one of the additional plants will not reduce the value of the objective function.

The iterative expansions approach, IEXPA, is quite similar except that the initial solution contains only one of

Table 12. Number of plants and number of models necessary

Number of Plants (N)	Number of Transportation Models to Choose Among $\binom{L}{N}$
1	$\binom{10}{1} = 10$
2	$\binom{10}{2} = 45$
3	$\binom{10}{3} = 120$
4	$\binom{10}{4} = 210$
5	$\binom{10}{5} = 252$
6	$\binom{10}{6} = 210$
7	$\binom{10}{7} = 120$
8	$\binom{10}{8} = 45$
9	$\binom{10}{9} = 10$
10	$\binom{10}{10} = 1$

the plants. The question asked is: "Will the addition of any one plant lower the value of the objective function?" The rule is: add the plant that lowers the objective function's value the most. The procedure continues until the addition of another plant will not lower the objective function's value.

Both methods differ from the theoretical ideal in that once a plant location is excluded from or included in the solution it cannot re-enter or be removed from the solution. In the theoretical optimization procedure, a plant location might be the best one location, not be included as one of the best two locations, yet re-enter the solution as one of the best three locations.

The transportation cost minimization curve is depicted in Figure 5. Note that the global transportation cost is minimized when every possible location has a plant. The general shape of the transportation cost function has been empirically derived in several studies (35, p. 14).

The addition of the processing cost function to the objective function does create some problems that must be considered. The procedure for minimizing Equation 9 depends on whether there are economies of scale in plant operations and whether or not production costs vary with respect to plant location. Figure 4 displays the four possibilities.

	Plant economies of scale	No plant economies of scale
Production costs independent	Case I	Case III
Production costs vary	Case II	Case IV

Figure 4. The four cases of the Stollsteimer approach

Case I assumes 1) economies of scale in plant operations, 2) plant costs are independent of plant locations, 3) long-run total plant cost functions take the form:

(14) $C_n = a + PX_n$

where a is greater than zero and independent of plant location, and 4) unit plant costs are a function of plant size.

Stollsteimer's first Case I assumption states that the plant cost function has an intercept value (a in Equation 14). The value of a is defined as the minimum average annual long-run cost of establishing and maintaining a plant (43, p. 636). Functions with an intercept have been criticized by Chern and Polopolus because

> ...theoretically the long-run total plant cost goes through the origin....It is reasonable to expect a very small, if any, intercept value if the TPC (total plant cost) function is continuous and all factors of production are completely divisible and are therefore treated as variables in the long run (4, p. 581).

The criticism is a classic example of a theoretical complaint about the assumptions of an operational model. Although there may not be a minimum plant size necessary for output to be produced, it may be necessary to allow fixed costs to enter the model's optimization because fixed costs may play an important role in investor's decision-making processes. Thus, although I tend to agree with the theoretical argument, fixed costs are operationally relevant. One might also observe that people arguing that the plant cost function passes through or very near the origin and then arguing that long-run functions are discontinuous because of the "indivisability of durable equipment" are being inconsistent. Surely, if the function is discontinuous for output levels beyond the origin the function can be discontinuous at the origin. Likewise, anyone that allows an intercept as Stollsteimer did would have trouble defending the lack of other discontinuities at other points as output is increased.

Assumption two simply says that plant location does not effect the plant cost function. Assumption three gives the form of the plant cost function and assumption four reiterates the fixed-cost concept. In any cost function with an intercept, unit plant cost will be a function of volume because the fixed cost charges per unit of output decrease as output increases.

Because of the assumptions made about production costs in Case I, they take on a simplified form. From assumption two we know that a and P are constant for all plants. Knowing Equations 11 and 12 and that a and P are constant, summing Equation 14 over N plants yields a total processing cost (TPC) function of the form:

(15) $TPC = N(a) + P(X)$

Thus, P times X is constant and it can be concluded that an additional plant adds to the total cost by the amount of the fixed costs (a). Figure 6 depicts the processing cost function. P times X is the intercept value.

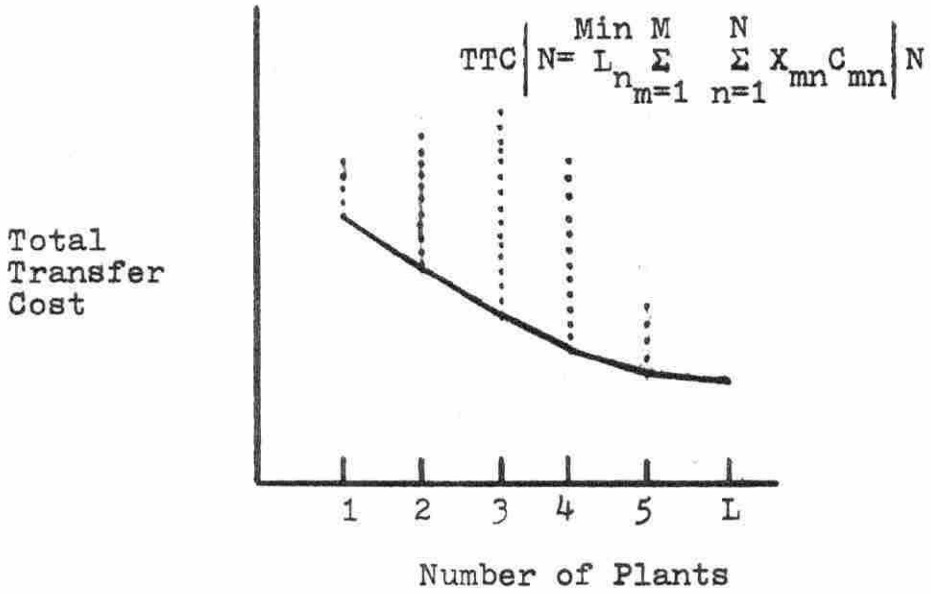


Figure 5. Minimized total transfer cost

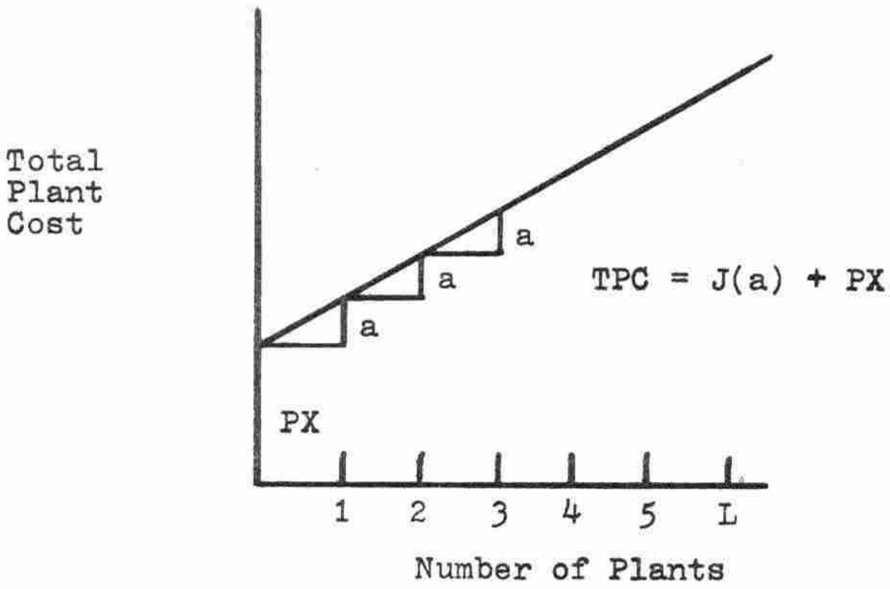


Figure 6. Plant cost

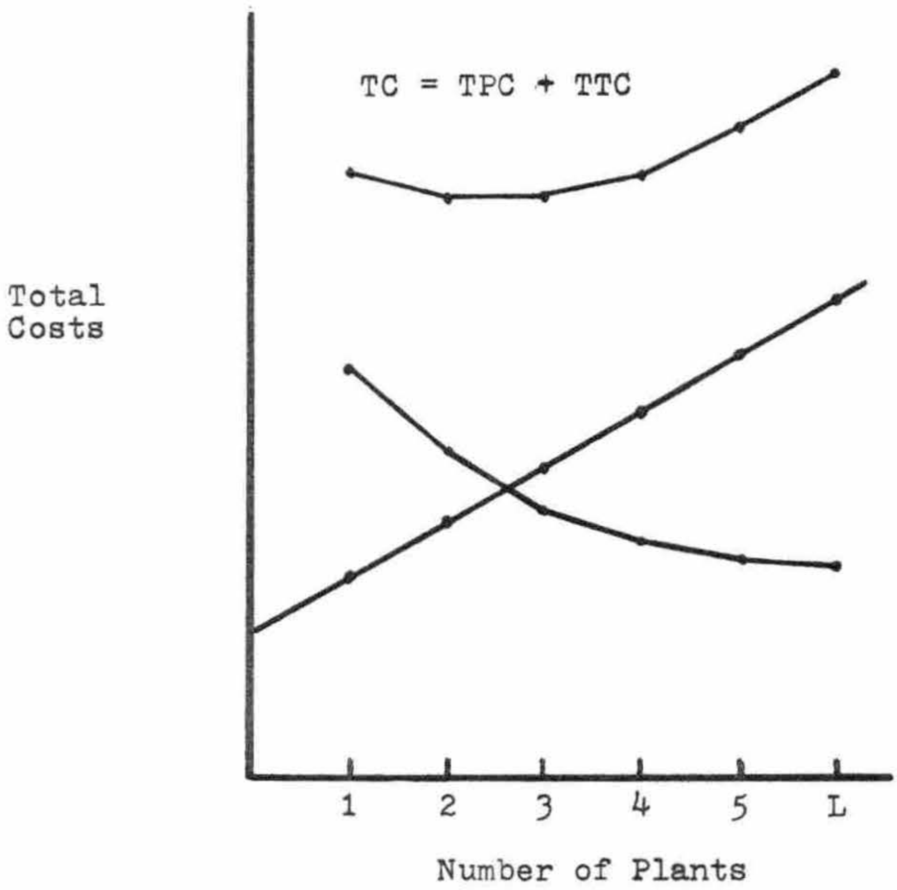


Figure 7. Total costs

Combining Figures 5 and 6 in Figure 7 we derive the graphical representation of Equation 9 for Case I.

Note that Equation 9 is drawn as a U-shaped curve (is convex downward). Assuming that Equation 9 can be represented by a U-shaped curve means that it was assumed that as additional plants are added, the decrease in total transportation cost is smaller than the increases in total cost caused by adding more plants. As stated earlier, total transportation costs decline as additional plants are added as long as the additional plant is closer than any other plant to at least one origin.

Case II considered by Stollsteimer assumes that the plant-cost function is linear in form but changes with location. In this case there would be L production cost equations each with a different P_n.

To solve Case II, unit plant processing cost values P_n are added to their respective columns in the transportation cost matrix. An envelope curve similar to the one in Figure 5 is derived in essentially the same manner using the transfer-variable production cost matrix to determine the minimum cost set of locations. By adding the fixed cost (N times a) values to the curve a total cost curve is again produced.

Case III, (no economies of scale in plant operations and plant costs independent of location) is quite easy to visualize. Fixed costs are zero because of the no economies of scale assumption (no fixed costs to spread over additional volume), therefore, production costs do not increase when additional plants are added. Minimizing Equation 9 becomes a problem of minimizing transportation costs. A plant will be located at each plant site that minimizes transportation costs for at least one origin.

Solution of Case IV (no economies of scale in plant operations and plant costs dependent upon plant location) proceeds similarly to Cases II and III. The transfer costs matrix is revised by adding to the appropriate columns the various in-plant costs as in Case II and the total plant cost--transportation cost matrix can be scanned to determine which location minimizes costs for each source. All locations minimizing costs for at least one source will be included in the solution.

Four classes of data are necessary for empirical application of the model:

1. Estimated or actual raw material from each origin,
2. A transportation cost matrix,
3. A plant cost function (or functions) which permits the determination of the cost of processing any fixed total quantity of material in a varying number of plants,
4. Specification of potential plant locations.

C. Transhipment

The transhipment algorithm was developed by Orden (34). It is basically a transportation problem

> with the additional feature that shipments may go via any sequence of points rather than being restricted to direct connections from one of the origins to one of the destinations (34, p. 277).

In Figure 8 the difference is exposed.

Transhipment allows for shipments from destination to source, from destination to destination and from source to source. Indeed, sources or destinations producing zero or consuming zero can be introduced as purely transhipment points.

A formal statement of the model follows. The following notation will be used:

M = number of sources, $m = 1,2,3,\ldots M$;

L = number of transhipment points, $l = 1,2,3,\ldots L$;

N = number of final destinations, $n = 1,2,3,\ldots N$;

a_m = quantity available at the m^{th} source;

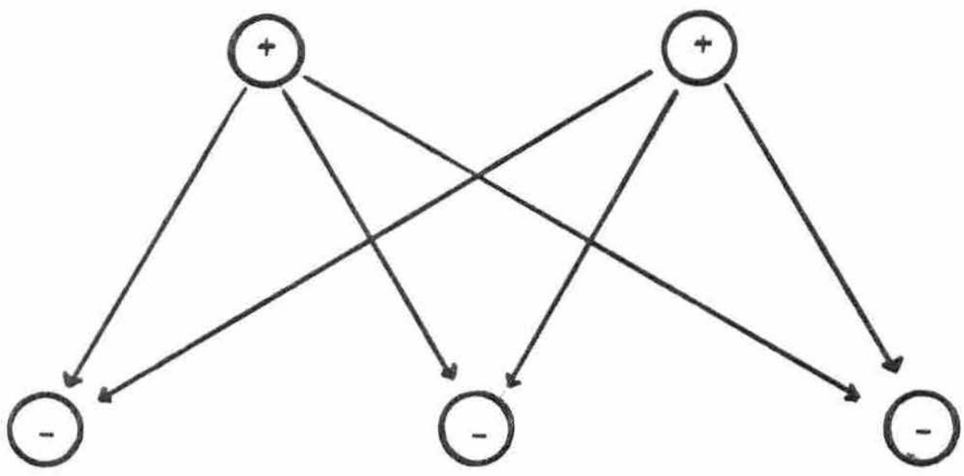
b_n = quantity desired by the n^{th} destination;

C_{ml} = per unit transportation costs from origins to transhipment points;

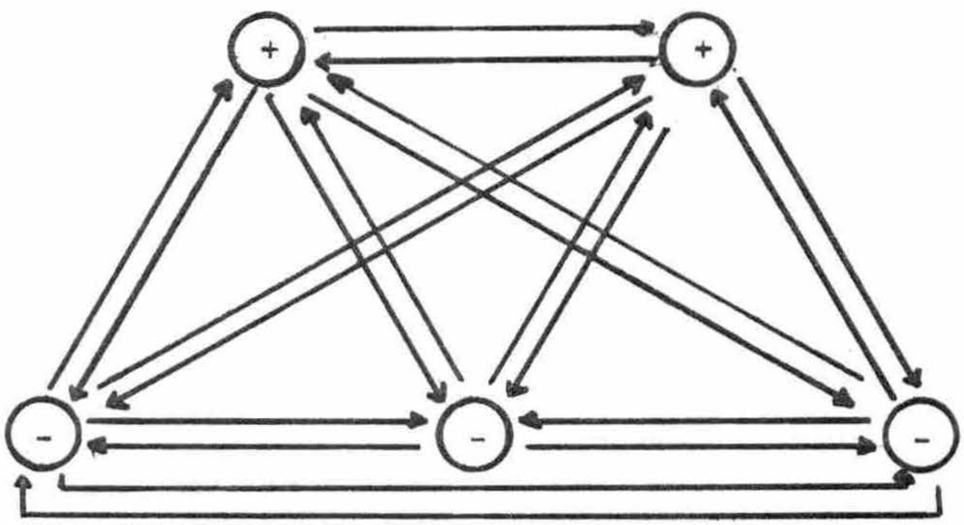
C_{mn} = per unit transportation costs from origins to final destinations;

C_{ln} = per unit transportation costs from the l^{th} transhipment point to the n^{th} final destination;

X_{mn} = number of units shipped from the m^{th} origin to the n^{th}



Panel A. Transportation activities



Panel B. Transhipment activities

Figure 8. Transportation activities compared to transhipment activities. Arrows indicate routes, + indicates supply nodes, - indicates demand nodes.

final destination;

X_{ml} = number of units shipped from the m^{th} origin to the l^{th} transhipment point;

T_{ln} = number of units shipped from the l^{th} transhipment point to the n^{th} final destination.

The objective function is to minimize shipment costs.

$$(16) \quad \sum_{m=1}^{M} \sum_{n=1}^{N} C_{mn}X_{mn} + \sum_{m=1}^{M} \sum_{l=1}^{L} C_{ml}X_{ml} + \sum_{l=1}^{L} \sum_{n=1}^{N} C_{ln}T_{ln}$$

The restrictions of the model are designed to 1) exhaust all sources of their products, 2) insure destinations of their quota, 3) require sources to tranship what is shipped to them, 4) insure that any quantity arriving at a destination above its quota is transhipped, 5) specify that points introduced as purely transhipment points ship the quantity shipped to them.

In order to be consistent with the following sections and to make the explanations more clear, sources or destinations acting as transhipment points will be treated as a separate entity from the same sources or destinations acting as primary suppliers of final destinations. By designating origins and transhipment points as stated above, the model is more easily compared to the previously stated transportation model. Also, this allows for shipments from an origin to itself although it will not appear as an X_{mm} shipment. With this formulation, there are but three basic equations necessary to insure that the model complies with the restrictions.

Because primary origins and final destinations are not transhipment points, restrictions three and four become equivalent to one and two, respectively, and restriction five becomes the relevant restriction for the transhipment points.

Stated mathematically, the restrictions are:

$$(17) \quad \sum_{n=1}^{N} X_{mn} + \sum_{l=1}^{L} X_{ml} = a_m, \; m = 1,2,3,\ldots M$$

For each origin, the sum of what a primary origin ships to final destinations plus what it ships to transhipment points must equal the quantity available.

$$(18) \quad \sum_{m=1}^{M} X_{mn} + \sum_{l=1}^{L} T_{ln} = b_n, \; n = 1,2,3,\ldots N$$

For each final destination, the sum of what it receives from origins plus the sum of what it receives from transhipment points must equal its demand.

$$(19) \quad \sum_{m=1}^{M} X_{ml} - \sum_{n=1}^{N} T_{ln} = 0, \; l = 1,2,3,\ldots L$$

For each transhipment point, the sum of what it receives from the origins minus what it ships to final destinations must be equal to zero.

D. Transhipment, Plant Size, Number and Location

Before explaining King and Logan's (22) plant location model, Sections A, B, and C of Chapter III will be linked by expressing each of the preceding problems in a linear programming tableau. The linear programming tableau will allow the reader to see how each of the first three sections serve as building blocks for the model in Section D. Throughout Section D one simplified five-region example will be used.

Figure 9 is a linear programming tableau expression of Equations 2 through 8.

The objective of the program is to find a set of X values such that the objective function is minimized and the restraint rows are satisfied. In matrix notation the X values are found such that the following matrix multiplication is accomplished:

$$(20)\quad \begin{bmatrix} C_{17} & C_{18} & C_{27} & C_{28} & C_{37} & C_{38} \\ 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_{17} \\ X_{18} \\ X_{27} \\ X_{28} \\ X_{37} \\ X_{38} \end{bmatrix} = \begin{bmatrix} \text{minimum} \\ a_1 \\ a_2 \\ a_3 \\ b_7 \\ b_8 \end{bmatrix}$$

In the first tableau the objective function is Equation 2':

$$(2')\quad X_{17}C_{17} + X_{18}C_{18} + C_{27}X_{27} + C_{28}X_{28} + C_{37}X_{37} + C_{38}X_{38}$$

and must be minimized.

Rows labeled S_1, S_2, and S_3 represent Supply Restriction 3:

$$(1)(X_{17})+(1)(X_{18})+(0)(X_{27})+(0)(X_{28})+(0)(X_{37})+(0)(X_{38})=a_1$$

ROWS	X_{17}	X_{18}	X_{27}	X_{28}	X_{37}	X_{38}	ROW TYPE	RHS	
Cost	C_{17}	C_{18}	C_{27}	C_{28}	C_{37}	C_{38}	Obj.	Min.	
S_1	1	1	0	0	0	0	=	a_1	
S_2	0	0	1	1	0	0	=	a_2	Q^S
S_3	0	0	0	0	1	1	=	a_3	$Q^S = Q^D$
D_7	1	0	1	0	1	0	=	b_7	
D_8	0	1	0	1	0	1	=	b_8	Q^D

Figure 9. Transportation tableau

$$(3') \quad \begin{aligned} (1)(X_{17})+(1)(X_{18})+(0)(X_{27})+(0)(X_{28})+(0)(X_{37})+(0)(X_{38})&=a_1 \\ (0)(X_{17})+(0)(X_{18})+(1)(X_{27})+(1)(X_{28})+(0)(X_{37})+(0)(X_{38})&=a_2 \\ (0)(X_{17})+(0)(X_{18})+(0)(X_{27})+(0)(X_{28})+(1)(X_{37})+(1)(X_{38})&=a_3 \end{aligned}$$

Equation 4 is similarly represented by rows D_7 and D_8:

$$(4') \quad \begin{aligned} (1)(X_{17})+(0)(X_{18})+(1)(X_{27})+(0)(X_{28})+(1)(X_{37})+(0)(X_{38})&=b_7 \\ (0)(X_{17})+(1)(X_{18})+(0)(X_{27})+(1)(X_{28})+(0)(X_{37})+(1)(X_{38})&=b_8 \end{aligned}$$

Equation 5 of the formulation in Section A is a requirement of the solution procedure and Equation 8 is easily provable and follows directly as a consequence of Equations 3 and 4 which have been shown to have their equivalent formulation in the current tableau.

Two changes are necessary to make this a Case II Stollsteimer tableau: the cost elements have the respective in-plant constant processing costs added to them and the quantities demanded (processed at each region) become variable.

A Case II Stollsteimer model is presented in Figure 10 because it incorporates more of the techniques important in latter models.

Three ($\binom{2}{1} + \binom{2}{2} = 3$) transportation models would have to be run to determine the two resulting points that would be on the minimized total transfer cost curve of Figure 5. First, the model would be solved with row D8 and columns X_{18}, X_{28}, and X_{38} eliminated. Then the model would be solved with row D7 and columns X_{17}, X_{27}, and X_{37} eliminated. The

ROWS	X_{17}	X_{18}	X_{27}	X_{28}	X_{37}	X_{38}	ROW TYPE	RHS
Cost	$C_{17}+P_7$	$C_{18}+P_8$	$C_{27}+P_7$	$C_{28}+P_8$	$C_{37}+P_7$	$C_{38}+P_8$	Obj.	Min.
S_1	1	1					=	a_1
S_2			1	1			=	a_2
S_3					1	1	=	a_3
D_7	1		1		1		$\geq$	0
D_8		1		1		1	$\geq$	0

Figure 10. Stollsteimer tableau

solution with the lowest objective function value would be on the minimum total transfer cost curve for one plant. The third model with all rows and columns included would then be optimized. Note that in Figure 10 rows D7 and D8 have been set greater than or equal to zero so that the plant processing volume is determined in the model.

The three points found by solving the three transportation--production models are similar to those in Figure 5.

The fixed cost values a and twice a are then added to the transportation--production model to arrive at the curve representing the minimized objective function. Note that the fixed cost values must be assumed to be the same for all locations for this procedure to be correct.

Only three factors can change the function's value: fixed costs of additional plants, economies of transportation and variable plant cost differentials. The third factor can be ignored if you are willing to assume per-unit processing costs are constant for all volumes and uniform over all possible processing locations as in a Case I Stollsteimer solution.

The transformation from transportation activities to transhipment activities can best be done by thinking of transhipment as two back-to-back transportation problems. Whenever a quantity of the good is transferred from origins to intermediate points, another set of transportation activities must be inserted to ship the commodity from the intermediate point to a demand region. Again a simple linear programming tableau will be used to illustrate. The same three origins and two destinations are retained.

In this limited transhipment tableau, only the origins will be allowed to act as transhipment points. Consistent with Section C, the origins will be numbered four, five, and six when transhipment activities are involved (whenever the origins act as destinations or secondary shippers).

The transhipment tableau for the simple example is presented in Figure 11. Figure 11 is called a limited transhipment tableau because all of the activities illustrated in Figure 8-B are not allowed.

The following activities are represented by the columns--shipments from primary origins to transhipment points and final destinations (the first 15 columns) and shipments from transhipment points to final destination (the last six columns). The transhipment activities are limited in that plants are not allowed to ship to each other or to transhipment points and one transhipment point is not allowed secondary shipment activities to another transhipment point.

The cost row contains the usual transportation cost elements which when multiplied by their respective flow (X) elements represent Equation 16'.

$$(16') \quad \sum_{m=1}^{3} \sum_{n=7}^{8} C_{mn} X_{mn} + \sum_{l=1}^{6} \sum_{n=7}^{8} C_{ln} T_{ln} + \sum_{m=1}^{3} \sum_{l=5}^{6} C_{ml} X_{ml} = \min$$

ROWS	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{24}	X_{25}	X_{26}	X_{27}	X_{28}	X_{34}	X_{35}	X_{36}	X_{37}	X_{38}	X_{47}	X_{48}	X_{57}	X_{58}	X_{67}	X_{68}		RHS
COST	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}	C_{47}	C_{48}	C_{57}	C_{58}	C_{67}	C_{68}		MIN
S_1	1	1	1	1	1																	=	a_1
S_2						1	1	1	1	1												=	a_2
S_3											1	1	1	1	1							=	a_3
D_7				1					1					1		1		1		1		=	b_7
D_8					1					1					1		1		1		1	=	b_8
T_4	1					1					1					-1	-1					=	0
T_5		1					1					1						-1	-1			=	0
T_6			1					1					1							-1	-1	=	0

Figure 11. Limited Transhipment

Rows S_1, S_2, and S_3 represent the supply constraint Equation 17'. Rows D7 and D8 represent the demand constraint Equation 18' and T4, T5, and T6 are the tableau's statement of Equation 19'. Restated, the constraints are:

$$(17') \quad \sum_{l=5}^{6} X_{ml} + \sum_{n=7}^{8} X_{mn} = a_m, \; m = 1,2,3$$

$$(18') \quad \sum_{l=5}^{6} T_{ln} + \sum_{m=1}^{3} X_{mn} = b_n, \; n = 7,8$$

$$(19') \quad \sum_{m=1}^{3} X_{ml} - \sum_{n=7}^{8} T_{ln} = 0, \; l = 4,5,6$$

The transformation of Figure 11 into a King and Logan model is much the same process of transforming a transportation model into a Stollsteimer model.

Formally stated, the problem is:

> There are various areas with given supplies of raw product (live animals) and/or given demand for final product (meat). Transportation costs per unit for live animals and meat are given and do not vary with quantity shipped...(1) where should processing plants be located and (2) what should be the optimum number and size of plants needed to move the animals through slaughter plants and to consumers at least aggregate cost? (43, pp. 94-95).

The model assumes:

1. Regional supplies of raw materials are known,
2. Regional quantities demanded are known,
3. Transportation costs between regions are given,
4. A single product firm (with one major raw material),

5. A planning situation in which present locations are not considered.

At this point, it should be noted that the meaning of transhipment activity is broad and includes any manufacturing process as well as aggregation, storage and grading, activities usually performed in transit.

As was the case in the Stollsteimer model, the solution procedure for a transhipment, plant location model depends on whether there are economies of scale and if plant (transhipment activity) costs vary with location. Four cases will again be examined.

In all four cases, the initial solution includes all possible plant locations and all are assumed initially to operate at the minimum point on their cost-volume relationship. A recursive procedure much similar to the iterative eliminations procedure used to solve the Stollsteimer model is used to determine which plants should and do remain in the optimal solution.

Referring again to Figure 4, in Case I there are economies of scale and per-unit production costs vary, depending on location. To solve Case I, the lowest possible average total processing costs (P_j) are added to the shipment cost from transhipment point to final destinations. The model is then optimized.

At this point the recursive procedure begins. The optimal flows from Solution 1 are used to determine how large the cost of the transhipment activity should have been compared to the minimum cost used in the initial solution. If the volume passing through a transhipment point was not sufficient to warrant the low cost transhipment charge, the P_j are adjusted so that the cost-volume relationship is properly reflected. The recursive procedure continues until the volume going through each transhipment point is consistent with the cost used.

For Case II when there are again economies of scale but plant (transhipment activity) costs vary with location, a different cost-volume relationship must be consulted for each plant at each stage in the recursive process. It is easy to see the need for the procedure if a new plant or plants is to be constructed. The cost-volume relationship would probably be different for the new plant than for existing facilities.

Thus in both Case I and Case II, the cost of moving the good from a transhipment point to a plant has added to it the cost of the transhipment activity. In Case I, one cost-volume relationship is used for all the transhipment points but for Case II a different cost-volume relationship would be consulted for each of the transhipment points. Figure 12 depicts the revised transhipment tableau of Figure 11. Note that the only difference is that the plant (transhipment

ROWS	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{24}	X_{25}	X_{26}	X_{27}	X_{28}	X_{34}	X_{35}	X_{36}	X_{37}	X_{38}	X_{47}	X_{48}	X_{57}	X_{58}	X_{67}	X_{68}		RHS
COST	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}	$C_{47}+P_4$	$C_{48}+P_4$	$C_{57}+P_5$	$C_{58}+P_5$	$C_{67}+P_6$	$C_{68}+P_6$		MIN
S_1	1	1	1	1	1																	=	a_1
S_2						1	1	1	1	1												=	a_2
S_3											1	1	1	1	1							=	a_3
D_7				1					1					1		+1		+1		+1		=	b_7
D_8					1					1					1		+1		+1		+1	=	b_8
T_4	1					1					1					-1	-1					=	0
T_5		1					1					1						-1	-1			=	0
T_6			1					1					1							-1	-1	=	0

Figure 12. Limited Transhipment with plant costs added

activity) costs have been added to the shipping costs from transhipment point to final destinations.

Cases III and IV with no plant economies of scale imply that the cost-volume relationship is constant. In both cases the recursive procedure is not needed.

In Case III, where production (transhipment activity costs) are independent of location, the same constant average total processing cost would be added to each of the transportation costs from transhipment point to final destinations. In Case IV a different constant per-unit transhipment activity cost would be added to the individual transportation costs.

In either Case III or Case IV, the solution would contain every transhipment point that would reduce the cost of moving the product from at least one origin to the final destination.

The following notation will be used for the mathematical statement of the model.

M = number of sources, $m = 1,2,3,...M$;

L = number of transhipment points (plants), $l = 1,2,3,...L$;

N = number of final destinations, $n = 1,2,3,...N$;

a_m = quantity available at the m^{th} source;

b_n = quantity desired by the n^{th} destination;

C_{mn} = per unit transportation costs from origins to final destinations;

C_{ml} = per unit transportation costs from origins to transhipment points;

P_l = average total transhipment activity (plant) costs at the l^{th} plant, is generally a function of volume;

C_{ln} = per-unit transportation cost from the l^{th} transhipment point to the n^{th} final destination;

X_{mn} = number of units shipped from origins to final destinations;

X_{ml} = number of units shipped from origins to transhipment points.

T_{ln} = number of units shipped from the l^{th} transhipment point to the n^{th} final destination.

The objective function is to minimize Equation 21:

$$(21)\quad \text{MIN} = \sum_{m=1}^{M}\sum_{n=1}^{N} C_{mn}X_{mn} + \sum_{m=1}^{M}\sum_{l=1}^{L} C_{ml}X_{ml} + \sum_{l=1}^{L}\sum_{n=1}^{N}(C_{ln}+P_l)T_{ln}$$

the cost of shipping from origins to final destinations plus the cost of the transhipment activity plus the cost of shipping from transhipment point to final destination is minimized.

The restrictions are basically the same as previously stated. The sum of what a final destination receives from origins and from transhipment points must be equal to the quantity required by the final destination.

$$(22)\quad \sum_{m=1}^{M} X_{mn} + \sum_{l=1}^{L} T_{ln} = b_n,\ n = 1,2,3,\ldots N$$

The sum of what an origin ships to plants plus what it ships to transhipment points must equal the quantity available at the origin.

$$(23) \quad \sum_{n=1}^{N} X_{mn} + \sum_{l=1}^{L} X_{ml} = a_m, \; m=1,2,3,...M$$

The sum of what a transhipment point receives from origins minus the quantity shipped from the transhipment points to final destinations is equal to zero.

$$(24) \quad \sum_{m=1}^{M} X_{ml} - \sum_{n=1}^{N} T_{ln} = 0$$

Also, as in all transportation problems, the activity levels (X_{mn}, X_{ml}, T_{ln}) and the cost values (C_{mn}, C_{ml}, C_{ln}) cannot be negative.

The analogue of this formulation can be found in Equations 16 through 19.

IV. OPERATIONALIZING THE MODEL

Chapter IV describes the sources and procedures used to derive the data elements necessary to operationalize a transhipment-plant-location model. Six data elements are necessary:

1. An area to study.
2. Locations of and supply available at each origin.
3. Locations of and demand at each destination.
4. Locations of possible transhipment points.
5. Transportation costs between origins, destinations, and transhipment points.
6. Knowledge of the transhipment (processing) point cost-volume relationship.

A. The Area Under Consideration

Plant location model users have been plagued with the problem of deciding how large the area must be in order to arrive at relevant solutions. Whenever borders are arbitrarily defined in a larger homogeneous supply region, it is impossible to know the effects of supply or demand centers and possible plant locations just beyond arbitrarily chosen borders. The problem is eliminated if institutional or geographic constraints enable the researcher to eliminate areas outside the borders because of legal restrictions or because of extreme geographic constraints. In general, the researcher's budget limits the size of the area covered and arbitrary boundaries are chosen and border effect problems evaluated.

To date, two approaches to border effect problems have been used. Perhaps most significant has been to include all of the area defined by very high production density (8). This might be termed the "island" approach. In effect the researcher contends that all relevant supply areas are included and there are no border effect problems.

A second approach has been to simply assume away border effects (36). In other words, ignore the problem and assume that all of the raw material produced in the area is also processed in the area.

The model in the study does not easily succumb to the island approach. The major, high density, homogeneous, hog-producing island is large and contiguous. Also, the farm-to-market activity takes place at the microcosmic level. Therefore, origins must be minutely defined in order to represent the proper producer decision tradeoffs.

However, the hog shipment problem has a characteristic that makes border effect problems manageable. Origins near final demand points would probably most efficiently ship hogs directly to nearby plants. In general, fewer buying stations were located in counties where plants were located whereas counties adjacent to counties with plants had a relatively high density of packer-owned buying stations.

Thus, an area surrounded by packing plants would not be expected to have transhipment points optimally located in border areas. Such an area was selected and is illustrated in Figure 13.

The approximately nine county area selected is located within the bounds of the densest hog producing region in the United States. On the average, over 450 hogs were sold per rural square mile and on the average, over 2.5 million hogs per year were sold from the area between 1966 and 1970.

A minor factor that could have influenced the solution was the existence of a large reservoir at the southwest boundary of the area. The existence of a limited-access, physical boundary should decrease border problems.

Counties included in the study were Tama, Benton, Iowa, Poweshiek, Keokuk, Marshall, and parts of Marion, Washington, Grundy, Hardin, Mahaska and Jasper.

B. Origins

Spatial researchers must decide between small origins and increasing the cost of the solution. In general, additional origins raise the cost of solving the model because of the additional activities required. Also, origins should be properly chosen so that the relevant tradeoffs are represented. For example, a person evaluating the flows of grain between nations would not need to define farms as origins in order to analyze the alternative shipments.

Townships were selected as origins because they were the smallest geographic unit for which production data was available. A township covers approximately 36 square miles and is usually a 6 by 6 square area. There were 148[1] townships that served as origins in the nine county region.

Two types of production data were available: county pig farrowing data and township hog marketing data. Both sources had advantages.

Pig farrowing data is more accurate because double counting of hogs sold more than once is eliminated. Also, pig farrowing data has been collected longer and the collection methods are considered more accurate. However, pig farrowing data was not reported for townships.

Available township hog marketing data was taken from county assessor's reports and when aggregated was found not to accurately estimate statewide marketings.

To incorporate both sets of data and the advantages of each, two assumptions were made. Pig farrowing data was adjusted for death losses and inshipments to arrive at a figure that accurately reflected county hog marketings. Also, it was assumed that township marketing data is biased, but proportionally biased for each township in the county.

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[1]Technically, there are more than 148 townships in the area because larger towns usually are a separate township. Smaller townships with low production are included in larger, bordering townships. Most notably, Tama and Toledo townships in Tama county are combined.

Using these two assumptions, adjusted county sow farrowing data was weighted by percentage figures derived from available township marketing data. In order to account for hog production cycles, a five-year average of county pig farrowing data was used to represent county pig farrowings.

The correction equation used was:

$$(25)\quad TM_{ij} = CSF_i\ (1 - (DL + I - 0))\ \frac{TM_{ij}^*}{CM_i^*}$$

where:

TM_{ij} = quantity available at township j in county i.

i = 1,2,...n counties.

j = $1,2,\ldots m_i$ townships in county i.

CSF_i = average number of pigs farrowed in the ith county between 1966 and 1970.

DA = per cent death loss adjustment in Iowa for 1969.

O = per cent outshipments in Iowa for 1969.

I = per cent inshipments in Iowa for 1969.

TM_{ij}^* = township marketing reported by county assessor in 1969.

CM_i^* = $\sum_{j=1}^{m_i} TM_{ij}^*$, county marketings reported by county assessors.

Table 30 in Appendix D lists raw data and the corrected values that were used and gives the data sources.

C. Final Destinations

Final destinations were slaughter plants. The twelve plant locations and their proportion of the region's supply are given in Table 13. The packers' market shares were estimated by considering distance from the supply area, plant size and the number of transhipment points owned by the packer within the area. Market shares for a particular area were estimates because accurate data from packers was not available.

The use of twelve final destinations might be criticized on the grounds that some of the twelve plants were not the closest plant to any of the origins. Twelve destinations were used because the companies located further from the region had existing buying stations in the area and because producers prefer a competitive market. Allowing five long-distance demand centers implicitly assumes that a high degree of competition was desirable in the optimal solution and that a high degree of competition prevails if twelve plants are competing for the hogs from the origins.

Demand was given on a yearly basis. Seasonal supply or demand variations were not allowed in the model.

D. Hog Transhipment Point Locations

A hog transhipment point is a marketing business where live slaughter hogs are bought and sold. Transhipment implies that a hog transhipment point is an intermediate stage in a longer shipment process. A hog transhipment point receives hogs from farmers and ships hogs to packing plants.

Price determination and physical transfer are the primary functions of transhipment points.

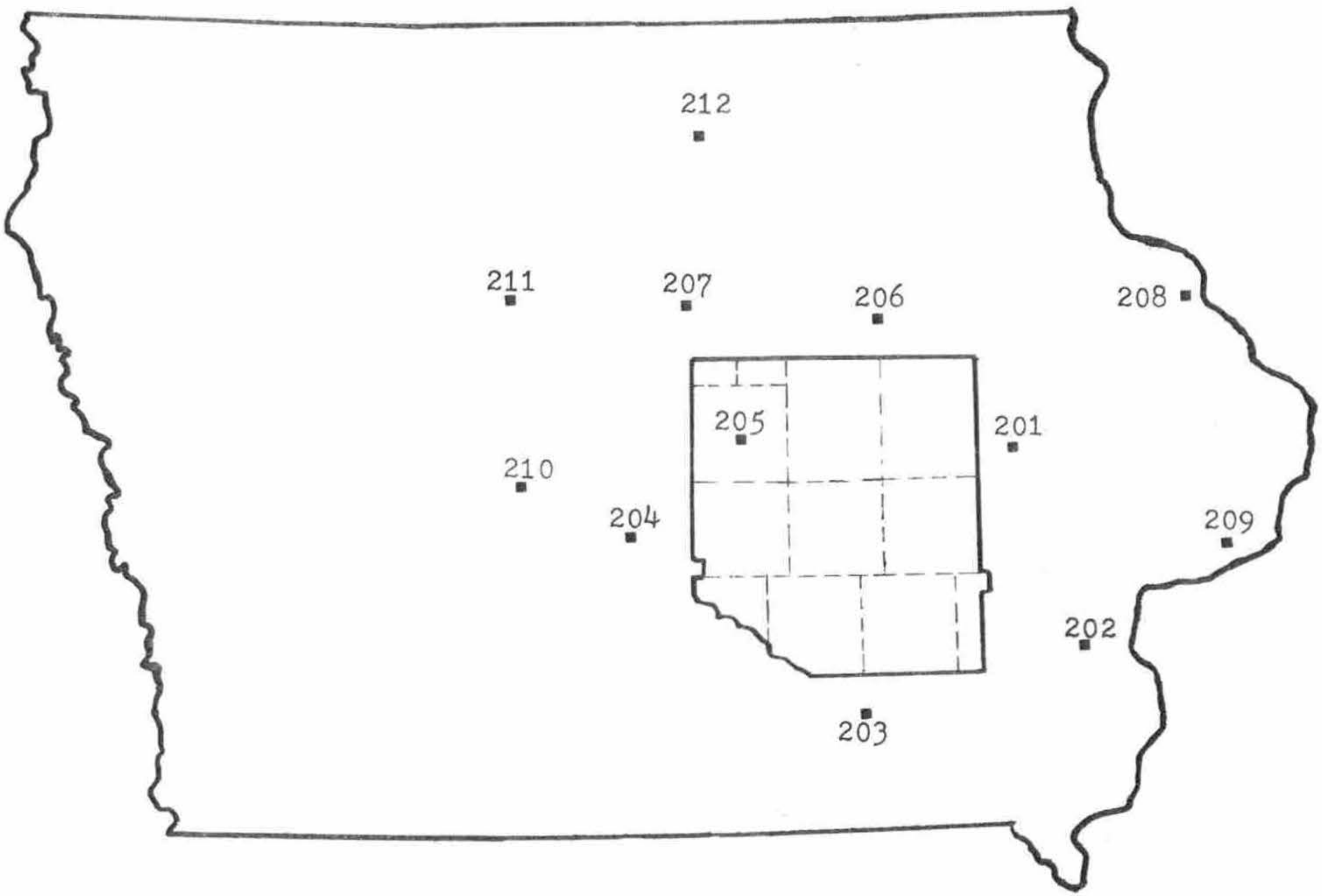

Figure 13. Location of the area studied and the 12 slaughter plants selected as final demand points

Table 13. Plant locations, per cent of total and number of hogs received from the area.

PLANT LOCATION AND NUMBER	PER CENT OF TOTAL	NUMBER OF HOGS RECEIVED FROM AREA
Cedar Rapids 201	28.0	718,640
Columbus Junction 202	7.5	192,490
Ottumwa 203	5.0	128,330
Des Moines 204	6.0	153,990
Marshalltown 205	8.0	205,320
Waterloo 206	28.0	718,640
Iowa Falls 207	8.0	205,320
Dubuque 208	2.0	51,330
Davenport 209	2.5	64,160
Perry 210	2.5	64,160
Fort Dodge 211	1.0	25,660
Mason City 212	1.5	38,490
Total	100.0	2,566,530

1. <u>Physical transfer</u>

In order to physically transfer hogs, a transhipment point needs:

1. Facilities for loading and unloading hogs from pick-up trucks, straight trucks and semitrailer trucks.
2. Holding and sorting pens.
3. Feed and water supplies.

In general, hogs arrive at buying stations in small trucks and leave in large trucks. Holding and sorting pens are used to group hogs from several producers into larger loads. Feed and water supplies are necessary if hogs are held for more than three or four hours.

2. Price determination

In order for price determination and sales to take place a hog transhipment point must have:

1. At least one buyer and one seller present.
2. Livestock weighing scales.
3. Telephone and radio communication.

The first requirement is an obvious prerequisite for any transaction. The second requirement is necessary because hogs are sorted, graded, priced and sold according to weight. Third, buyers need to communicate with packing plant buyers and to listen to current USDA market quotations and trends broadcast on the radio.

3. Classifications

Hog transhipment points can be classified as:

1. Livestock auctions.
2. Packer-owned buying stations.
3. Private dealers and order-buying stations.

At livestock auctions, prices are determined by continuous competitive bidding by several buyers. Auction houses usually hold one sale per week where all species of livestock are sold. Auction barn managers do not usually bid on hogs but act as a price reporter, certified weigher and financial intermediary between buyer and seller. The seller agrees to pay the auction company a percentage of the total sale value.

Packer-owned and private buying stations operate daily and only handle hogs. Prices are determined by bargaining between the hog producer and the single buying station manager or owner.

Packer-owned buying stations are managed by salaried packing company employees while private dealers and order buyers either receive a per-head commission from the packer or profit by bargaining with the packer for a higher price than the dealer paid the producer.

National Farmer's Organization (NFO) collection points and Interstate Producer's Livestock Association buying points were considered the same as private buying stations.

The location of possible transhipment points were collected from a survey of packers and a listing of registered dealers, order buyers and auction markets compiled by the United States Department of Agriculture (1).

The 120 dealers, order buyers, packer buyers and auction markets are shown in Figure 14.

In actuality, 120 probably overstates the number of physical facilities because the United States Department of Agriculture listing included all people registered to buy or sell livestock. A few of the registrants probably do not have the facilities that satisfy the transhipment point criteria. It was assumed that all registrants met the transhipment point criteria. Auction markets and packer-owned buying stations generally do satisfy the criteria.

Addresses of the buying stations were given by town and in general the buying stations may have been located as much as 5 to 10 miles from the community. In order to estimate distances to and from the buying stations, it was assumed that all buying stations were located in the community for which their address was given.

A complete list of buyers by township is included in Appendix B, Table 28.

E. Transportation Costs

The following section describes the theory, assumptions, data sources and procedure used to derive hog shipment cost estimates. The cost estimates are based on a revised short-run classical cost theory. The theory sets the organizational pattern for the remainder of the paper.

1. Revised short-run classical cost theory

Cost theory is used to describe the relationship between the cost of a firm's output and the quantity of output produced.

a. Classical cost theory   In short-run classical cost theory, costs are classified as either fixed or variable. Costs that do not change if the quantity of output changes are fixed costs. Costs that change when output changes are called variable costs.

Long-run classical cost analysis assumes that all costs are variable with respect to quantity of output produced.

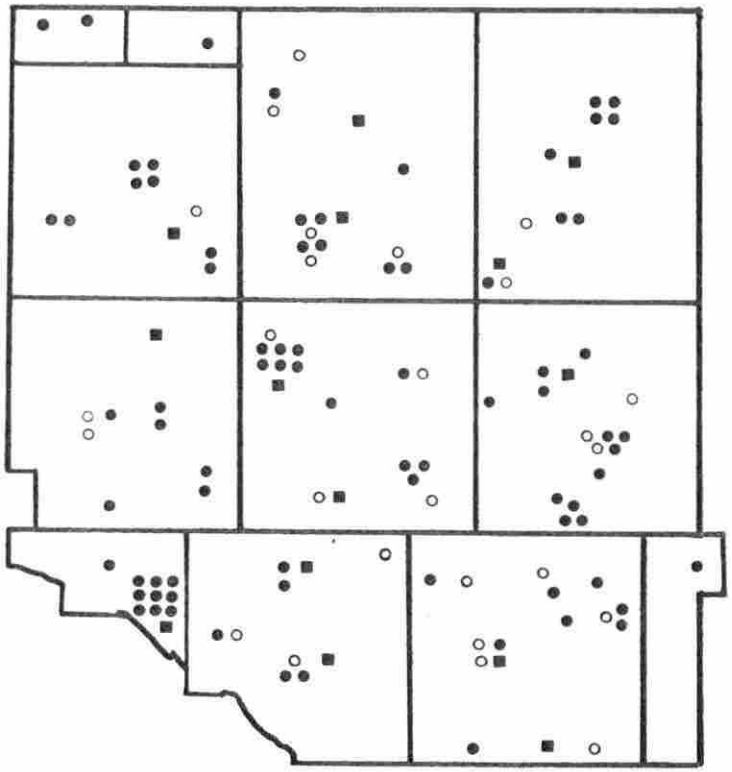

Figure 14. Locations of 120 auctions (▪), dealers (•), and packer buyers (◦) in the area

For example, a manufacturer of candy bars produces one-million more candy bars this year than he produced last year. Assuming the plant manager's salary hasn't changed, the manager's salary is fixed with respect to quantity changes within the two year period. Long-run cost analysis would allow the plant manager's salary to vary with respect to output. In this case, two years has been arbitrarily defined as the short-run--that period for which the manager's salary is fixed.

Seldom are applications of short-run classical cost analysis straightforward. Suppose the candy bar plant manager receives one cent per candy bar salary bonus for each candy bar over 10 million produced. The cost of the plant manager's services are fixed up to 10 million and variable for quantity changes above 10 million.

Other complications arise if the candy-bar-making machine's operating rate is allowed to fluctuate. Suppose that output is the same two consecutive years. The first year the plant operates eight hours per day and each of the candy-bar-making machines is operated twice as fast. It is logical to expect the cost of producing a candy bar would be different for each operating procedure.

Still other problems can be conceived that classical cost theory will not solve. Revisions are often made and a revision is required before classical analysis can be applied to the hog shipment problem.

b. <u>The hog shipment revision</u> Instead of candy bars, the output of the production process was measured in hog-miles. Hog-miles are calculated by multiplying the number of hogs hauled by the distance shipped. If eight hogs are shipped ten miles, eighty hog-miles of output result.

Classical analysis must be slightly revised in order to allow changes in the number of hogs hauled and changes in the number of miles traveled.

Therefore, some costs were <u>fixed</u> with respect to distance and <u>variable</u> with respect to the number of hogs hauled while other costs were <u>fixed</u> with respect to the number of hogs hauled and <u>variable</u> with respect to distance. If either distance or number of hogs hauled was constant, the analysis was strictly classical.

In summary, the revised analysis was classical in two dimensions because of the two dimensions of hog-miles: distance and number hauled.

c. <u>Average and total costs</u> One final concept needing clarification is the relationship between total cost and per-unit costs. If an element of total cost is fixed with respect to quantity of output, average cost declines as output is increased.

For example, assume the cost of a farmer bargaining with buyers is fixed at four dollars both with respect to distance and number hauled. If eight hogs are hauled five miles, the cost of bargaining per hog-mile is 10 cents

($\frac{\$4.00}{5X8}$). If 16 hogs are hauled five miles or if eight hogs are hauled 10 miles the cost per hog-mile falls to five cents ($\frac{\$4.00}{5X16} = \frac{\$4.00}{10X8} = 5¢$) per hog-mile.

2. Assumptions

Assumptions can be classified as either theoretical or operational. Theoretical assumptions are those made by the theorist while building a theory. Operational assumptions are made by the researcher because real world situations don't conform to the theory and because data is not available.

Stating operational assumptions sometimes simply means stating how the theory was applied. Many of the operational assumptions are described when they are used for deriving the cost estimates. Theoretical assumptions were omitted and left to textbooks on microeconomic theory. The following operational assumptions set the stage for this section:

1. Slaughter hogs weighed 242 pounds (the average weight of hogs slaughtered in Iowa in 1969).
2. Producer's time spent in marketing activities was valued at $2.50 per hour for the whole year.
3. All hogs were shipped in 16-, 30-, and 45-head lots.
4. Sixteen-head groups were taken to market in pickup trucks; 30- and 45-head groups were marketed in commercial straight trucks.
5. Published truck tariffs properly reflect the cost of the truck operation and the driver's wage.

Assumptions one and two reflect the absence of seasonality. It is well known that the average weight of slaughter hogs and the value of a producer's time vary for different seasons of the year. By defining yearly cost estimates, seasonal variations were assumed away.

Assumption three fixes the hog dimension of hog-miles at three levels and assumption four specifies a transportation mode for each level. Assumptions three and four were the critical assumptions that enabled the revised classical cost framework to be applied. After specifying the three levels, all that remained was a classical description of costs as the miles dimension of hog-miles was allowed to vary.

Assumption five reflects an assumed competitive equilibrium pricing for trucking services. Interpreted, this means that if trucking firms are making excessive profits, other firms will enter the industry until profits decrease.

3. Cost development procedure

By assuming that hogs are shipped in three lot sizes all that remains is to describe how costs change as distance changes. A cost-distance relationship will be defined for pickup trucks and commercial vehicles. Sixteen-head loads were moved in pickup trucks; 30 and 45-head loads were moved in commercial straight trucks.

a. 16-head lots Hogs in 16-head lots are assumed to be moved in two eight-head loads in producer-owned pickup trucks. Fixing the number of hogs at 16 allows concentration on the miles (distance) dimension.

Pickup truck costs were synthesized from data available on pickup operating costs and from assumptions about the costs of hauling hogs in a pickup.

1) <u>Costs variable with respect to distance</u>

Three kinds of costs were allocated on a per-mile basis:

1. Operating costs.
2. Depreciation.
3. Producer's labor cost while driving the truck.

Operating costs for pickup trucks were based on Iowa State Highway Comission data for 1,419 pickups driven 13.5 million miles in 1969. Highway Commission data was used because accurate farm pickup truck operating expense data was not available.

Highway Commission cost data included all costs of repairs and periodic maintenance activities that could be associated with its one-half-ton pickups.[1] However, the Highway Commission does not pay three per cent state sales and seven cents per gallon state fuel taxes or four cents per gallon federal fuel tax. To incorporate per gallon fuel taxes, it was assumed that pickup trucks averaged 15 miles per gallon.

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[1] Lucas, Thomas, Iowa Highway Commission, Ames, Iowa. Data from equipment usage analyses. Private communication. 1970.

One final adjustment was made to the Highway Commission data. The Highway Commission bought gasoline in very large quantities and received quantity discounts. Also, they carried less than normal amounts of insurance and did not pay license fees. A two cent per mile adjustment for these factors was made.

Depreciation and labor expenses were added to truck operating expenses.

Depreciation was based on an assumed $2,500 initial value and $500 value at the end of a five-year period. The $2,000 decrease in value was allocated at $400 per year. To allocate depreciation on a per-mile basis, it was assumed that farmer-owned pickups were driven 7,000 miles per year (52, p. 21).

In order to allocate labor cost on a per-mile basis, it was necessary to assume the producer drove the truck and averaged 45 miles per hour. Assuming a $2.50 per hour wage rate, the farmer's driving time cost $0.055 per mile.

Table 14 summarizes variable cost calculations.

2) <u>Costs fixed with respect to distance</u> In addition to variable costs, producers face additional cost factors that are fixed with respect to distance. These cost factors are time spent preparing and cleaning the truck, truck bedding costs and time spent bargaining with buyers.

Bargaining time was assumed <u>not</u> to vary as the number of hogs available for sale varies. Thus, it was necessary to

Table 14. Pickup truck costs variable with respect to distance

Fuel[1]	$137,983.44
Maintenance labor[1]	87,281.51
Sales tax (.03 X $137,983.44)	4,139.50
State and federal gas taxes (13.7 million miles divided by 15 equals the number of gallons; number of gallons times $0.11 equals total tax)	100,464.79
Two cents per mile adjustment for lower fuel price, additional insurance and license fees.	273,995.00
Total operating cost for 13.7 million miles.	$710,870.14
Total operating cost per mile. ($710,870.14 divided by 13.7 million miles)	$0.0519
Depreciation per mile. ($400 per year divided by 7,000 miles per year)	0.0571
Labor cost per mile. ($2.50 per hour divided by 45 miles per hour)	0.0555
Total variable cost per mile.	$0.1645

[1]Lucas, Thomas, Iowa Highway Commission, Ames, Iowa. Data from equipment usage analyses. Private communication. 1970.

include bargaining time as a cost in order to properly estimate per head costs when the number of hogs sold varies. In all cases, 30 minutes was allowed for bargaining and receiving bids.

Cleaning and preparing the truck were assumed to take 30 minutes and 50 cents was allocated for truck bedding costs.

Table 15 summarizes fixed cost calculations.

Table 15. Pickup truck costs fixed with respect to distance

Truck preparation and cleanup. (30 minutes at \$2.50 per hour)	\$1.25
Bargaining time. (30 minutes at \$2.50 per hour)	1.25
Truck bedding.	.50
Fixed pickup truck costs.	\$3.00

3) <u>Total cost</u> In order to arrive at total variable cost, it was necessary to multiply variable cost per mile times distance. To arrive at total cost, fixed cost was added to total variable cost. The equation for total costs is:

(26) $\$3.00 + \$0.1645(\text{Round-Trip Distance}) = \text{Total Pickup Truck Cost}$

Because the farmer was assumed to have 16 head available for market, the fixed costs of preparing and cleaning the truck, bargaining and bedding were distributed among all 16 while the distance-variable costs were distributed among the number of head carried per haul. Dividing fixed costs by 16 and distance-variable costs by eight, the cost-per-head equation was derived:

(27) $0.187 + $0.02056(Round-Trip Distance) = Pickup Truck Cost Per Head

One final factor was considered. In general, farmers traveling to nearby towns make multipurpose trips. A producer may stop to pick up feed or spend leisure time in the local community. To compensate for multipurpose trips, the variable costs of trips less than 15 miles were reduced by one-fourth.

b. Commercial vehicle rates Commercial vehicle rates were based on the Iowa Better Trucking Bureau, Inc., Operator Tariff No. 1. The Iowa Better Trucking Bureau tariff was used because of the large number of truckers using the rates. The livestock rates, even though published in 1964, were very similar to those in other tariffs published in 1971.

1) Costs variable with respect to distance Truck charges and producer's time and expense traveling to and from market vary with respect to distance.

The basic Iowa Better Trucking Bureau schedule was quite simple. From Table 16 it is apparent that it costs seven cents per one-hundred pounds to move hogs five miles or less, 25 cents per one-hundred pounds to move hogs 70 miles.

However, the notes following the rate schedule in Table 16 complicated cost calculations.

Table 16. Commercial vehicle rates (9, p. 179)

Item 405: Livestock, all kinds (see notes 1 through 4) over 4,00 pounds.

MILES	CENTS PER 100 POUNDS	MILES	CENTS PER 100 POUNDS
5 or less	7	127	33
8	10	131	34
10	12	135	35
12	14	139	36
16	15	143	37
20	16	147	38
25	17	151	39
30	18	155	40
35	19	159	41
40	22	163	42
45	23	167	43
50	24	171	44
70	25	175	45
79	26	179	46
88	27	183	47
97	28	200	48
106	29	207	49
115	30	214	50
119	31	221	51
123	32	228	52

Note 1. Charges on pickup shipments are subject to Item 90-95.

Note 2. Rates on sheep are 10 cents per 100 pounds higher than rates on other livestock.

Note 3. For distances over 228 miles add one cent for each additional six miles.

Note 4. Minimum weights:

Straight trucks: 75 miles or less, 8,000 pounds.
76 to 125 miles, 10,000 pounds.
over 126 miles, 12,000 pounds.

Semi-trailers: 100 miles or less, 16,000 pounds.
101 to 150 miles, 26,000 pounds.
over 151 miles, 28,000 pounds.

Note one applies only if two or more stops are made in order to load the truck. I assume the hogs are picked up from one owner and from one location and thus this note does not apply.

Note two obviously doesn't apply and note three simply extends the rates for distances beyond 228 miles.

Note four was the complicating factor. Note four gives the minimum weights for the various length hauls. The note says that if a producer wants to move less than 8,000 pounds (33 head) less than 75 miles, he must pay for 8,000 pounds. If a producer wants to move less than 10,000 pounds (42 head) between 76 and 125 miles he must pay for 10,000 pounds. For distances of 126 or more miles producers must pay for at least 12,000 pounds (50 head).

There are important ramifications for producers with a given number of hogs to sell.

For example, the 30-head load size (30 X 42 = 7,260 pounds actual weight) will be paying for 8,000 pounds for hauls less than 75 miles, 10,000 pounds for hauls between 76 and 125 miles and for 12,000 pounds for hauls over 125 miles.

The 45-head (10,890 pound) load fares somewhat better. For distances up to 125 miles, a producer would pay for the actual weight of the hogs. Beyond 125 miles he would be charged for the 12,000 pound minimum. Per-head costs for 30- and 45-head loads are summarized in Table 17.

Table 17. Truck cost per head for 30 and 45 head loads

MILES	$ PER HEAD		MILES	$ PER HEAD	
	30 Head	45 Head		30 Head	45 Head
5 or less	.19	.17	127	1.32	.88
8	.27	.24	131	1.36	.91
10	.32	.24	135	1.40	.93
12	.37	.34	139	1.44	.96
16	.40	.36	143	1.48	.99
20	.43	.39	147	1.52	1.01
25	.45	.41	151	1.56	1.04
30	.48	.44	155	1.60	1.07
35	.51	.46	159	1.64	1.09
40	.58	.53	163	1.68	1.12
45	.61	.56	167	1.72	1.15
50	.64	.58	171	1.76	1.17
70	.67	.61	175	1.80	1.20
79	.87	.63	179	1.84	1.23
88	.90	.65	183	1.88	1.25
97	.93	.68	200	1.92	1.28
106	.97	.70	207	1.96	1.31
115	1.00	.73	214	2.00	1.33
119	1.03	.75	221	2.04	1.36
123	1.07	.77	228	2.08	1.39

Producers with more than 50 head (approximately 12,000 pounds) would not pay for weight not shipped.

Producer time and travel expenses were added to the commercial vehicle rates. Producers often accompany their hogs to market in order to receive payment, observe weighing or in other ways supervise the marketing process. It was assumed that producers visit the market in which his hogs are sold one-half of the time. It was assumed that the farmer visits the market only 50 per cent of the time because sorting and pricing is often done before the hogs leave the farm. Also, producers deliver hogs to the same market year after year and often do not feel it is necessary for them to supervise the marketing process.

It is assumed that the producer drives to market and vehicle expenses are 10 cents per mile. The cost of the producer's time is based on 60 miles per hour average driving speed and $2.50 per hour wage.

2) <u>Costs fixed with respect to distance</u> In addition to trucking costs, 30 minutes of the producer's time was allocated for bargaining and dealing with buyers. Bargaining was the only cost factor fixed with respect to distance.

3) <u>Total cost</u> Total cost was derived by adding variable costs to fixed costs. In this case the problem was more difficult because of the discontinuous nature of the commercial truck charges.

In the 30-head case, total cost per head was found by first dividing fixed cost by 30 to find fixed cost per head. Because producer's time and travel expenses were incurred only 50 per cent of the time, it was calculated using one-way distances rather than round-trip distances. The per-mile cost of the producer's time and car expense must be multiplied by distance to arrive at total cost for the producer's time and transportation. Dividing by 30, cost per head is obtained.

Commercial truck charges were obtained by finding the one-way distance in the miles column and selecting the corresponding charge per head from the 30-head column.

Total cost per head was found by adding fixed cost per head, producer's time and travel expense per head and the value obtained from Table 14.

Total per-head cost for 45-head loads were obtained similarly.

4. Summary

Figure 15 shows the relationship between cost per head for different load sizes as distance increases. The 16-head load size was most expensive and the cost differential gets larger as distance increases. The 45-head load size was least expensive. The difference between the 45-head load per-head cost and the 30-head load per-head cost increases as distance increases.

The kinks in the 30- and 45- head cost curves are caused by the Iowa Better Trucking Bureau's minimum weight requirements.

In reality, the 45-head lot costs approximate the costs for loads of 45 or more head for shipments under 125 miles because 45-head loads achieve the lowest truck charge per head. The farmers cost per head becomes quite small for 45-head loads. Beyond 125 miles, the 45-head load begins paying for pounds not shipped and thus costs per head of larger loads are overstated.

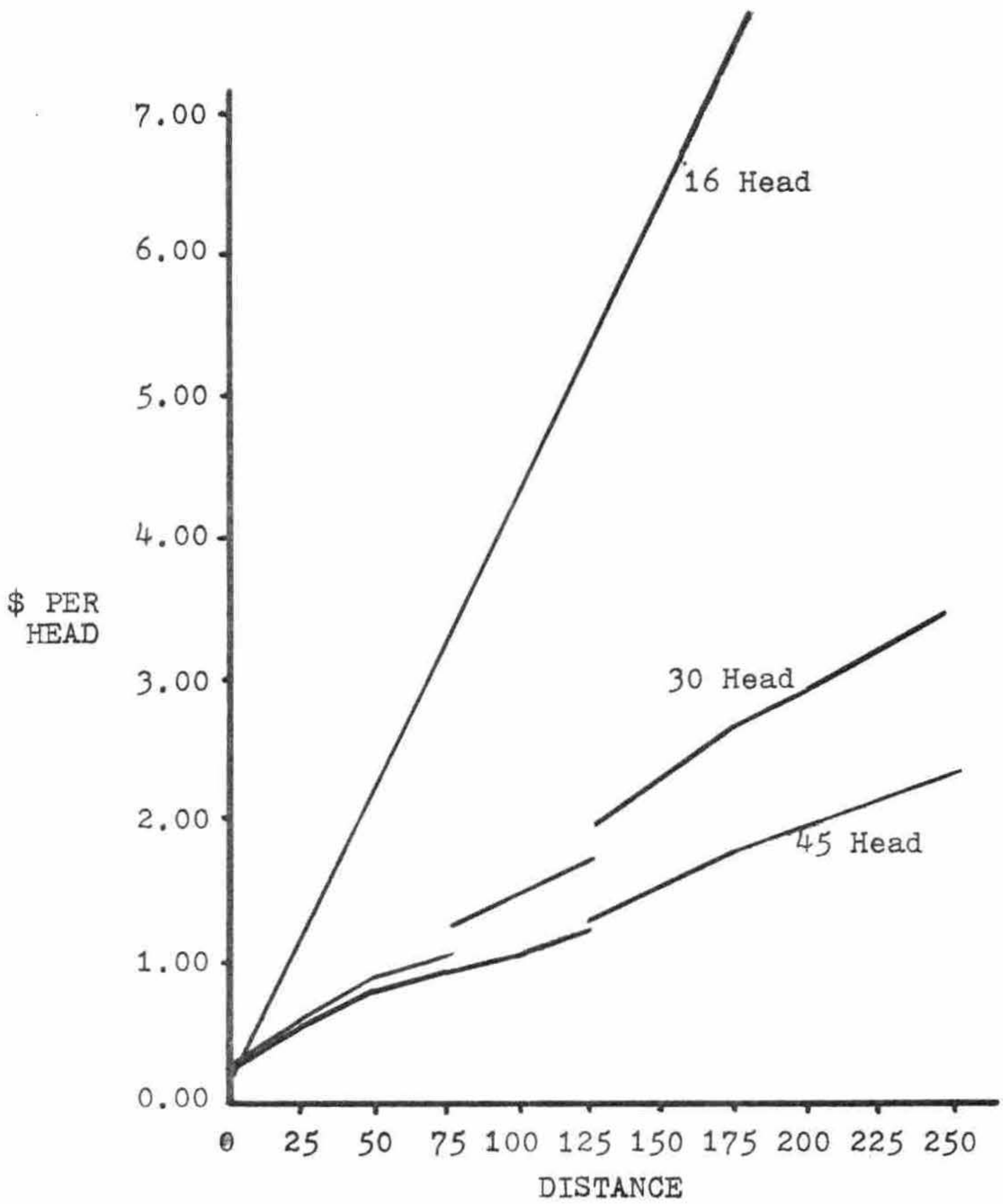

Figure 15. Cost per head versus distance for 16-, 30-, and 45-head loads.

The cost coefficients for 16-head lots can generally be said to be applicable to hogs shipped in pickup trucks. The costs closely estimate costs of 8 and 24-head lots or any other multiple of 8 head.

F. The Buying Station Cost-Volume Relationship

In the recursive process used to solve the King and Logan plant size, number and location model a buying station (plant) cost-volume relationship was needed so that the costs could be adjusted to agree with volume after each step through the solution.

The Broadbent-Perkinson (3) conclusions were quite severely criticized in Chapter II. However the data they provided was used to supply the needed buying station cost-volume relationship.

The data was readily adaptable because:

1. The volume of buying stations ranged from 13,000 to 130,000.
2. Procurement patterns in Illinois are felt to be quite similar to those in Iowa.
3. Overhead costs were not included. Since this application of the King and Logan model was designed to select the optimal set of buying stations from the existing set of buying stations, overhead and other fixed costs are not relevant decision variables because the buying stations are already in existence.

Table 18. Cost-volume relationship regression results for Equation 28.

ANALYSIS OF VARIANCE				
SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F-RATIO
Regression	1	2.6468	2.64688	89.6926
Residual	46	1.3574	0.02951	
Corrected Total	47	4.0042		
R SQUARE = 0.6610				

VARIABLE	COEFFICIENT	T-VALUE
X_1	-0.3889	-9.4706**
Intercept	3.503156	8.2094**

**Significant at 99 per cent level.

4. The data represents yearly relationships and this study uses yearly data.

The regression equation reported by Broadbent and Perkinson obviously was not applicable because the King and Logan model used does not generate capacity utilization or replacement value of land and facilities per hog handled. A linear regression routine was used to estimate a cost-volume relationship, Equation 28:

(28) $\log Y = a + b_1 \log X_1$

where Y is cost per head and X_1 is volume passing through the buying station in a given year. The analysis of variance information is summarized in Table 18. The data used in the

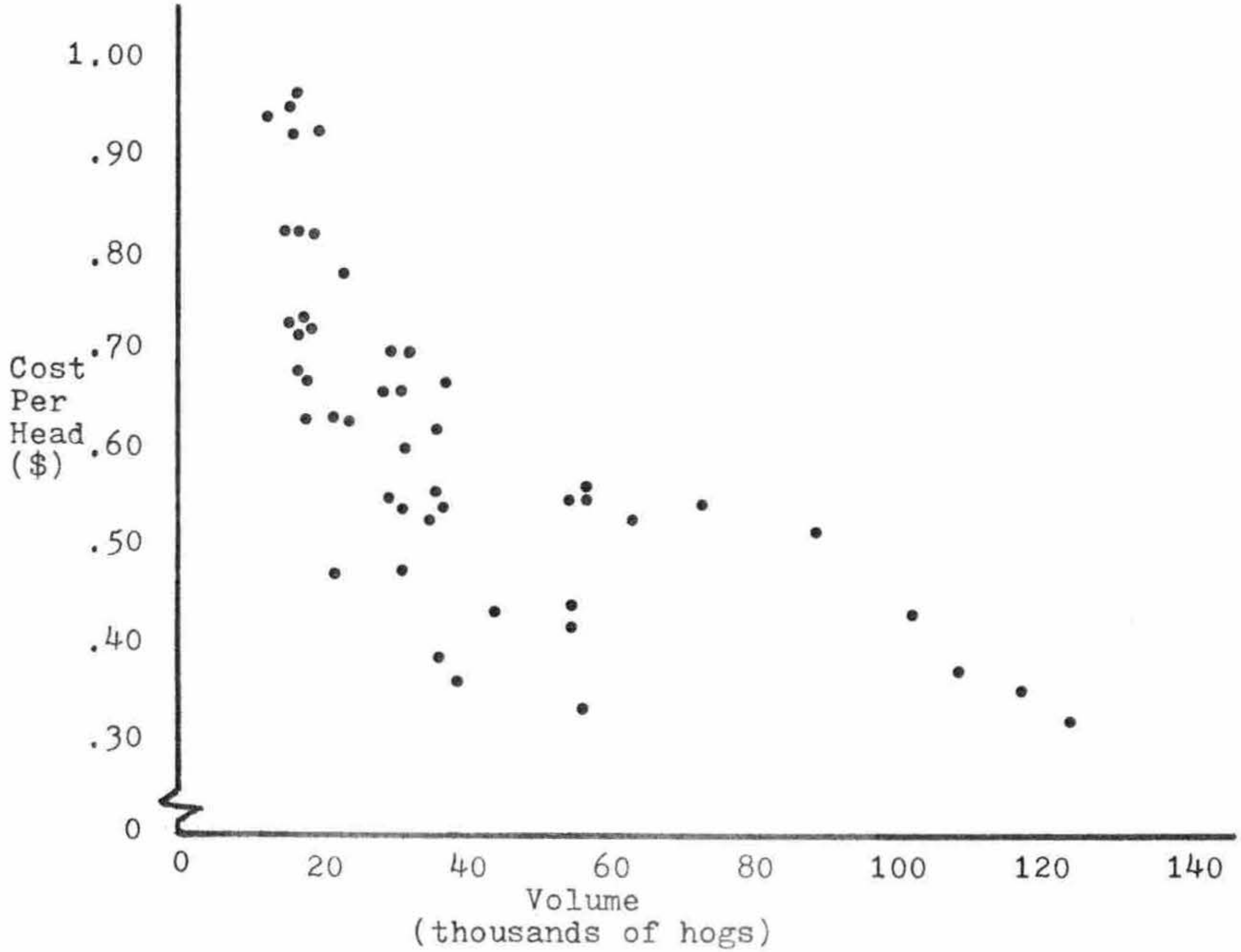

Figure 16. Broadbent-Perkinson cost volume observations for 48 local, Illinois markets (2, p. 9)

regression is found in Table 9, Chapter II and is shown graphically in Figure 16.

V. RESULTS

Two sets of exogenous conditions distinguish two basic models that were optimized. The first model's right-hand sides approximate real world conditions. The second model is designed to estimate expected future lot size and production changes.

In both models, origins could ship to the nearest 10 buying locations and six closest plants. Each buying location was allowed to ship to every plant.

In order to approximate the real world, the number of hogs shipped in various sized lots was estimated. The number of hogs shipped in various lot sizes for the Upper Missouri River Basin was reported by Ward and is duplicated in Table 19. Using Ward's data as guidelines, it was assumed in the real world model that 25 per cent of the hogs were shipped in 16-head lots, 50 per cent in 30-head lots and 25 per cent in 45-head lots.

Table 19. Lot size distribution (53, p. 94)

LOT SIZE	PER CENT OF HOGS MARKETED
10 or less	1.66
10 to 30	44.39
30 to 50	47.53
50 or more	6.42
	100.00

Table 20. A comparison of lot size distributions for Model I and Model II

LOT SIZE	PER CENT OF 1966-70 Average MODEL I	MODEL II
16	25	20
30	50	50
45	25	40
Total	100	100

Model II assumes a decrease in the number of hogs shipped in 16-head lots and an increase in the proportion shipped in 45-head lots. Also, it is assumed that hog production in creases 10 per cent over the 1966 through 1970 level and that all of the increase is shipped in 45-head lots. Table 20 summarizes lot size distributions for the two models.

The results of each model are presented under the following five headings.

1. Total cost and cost per head.
2. Number, location and size of the buying stations.
3. Per cent of hogs from each lot size that are transhipped.
4. Per cent of each plant's supply from the region that is received from transhipment points.
5. Total number of hogs transhipped versus the total number of hogs available for shipment.

The model's results are summarized in Tables 21 through 26 and in Figures 17 and 18.

A. Model I

Model I is used to optimize shipment patterns under current conditions and to approximate costs of the "real world."

1. The optimal solution

In the initial solution of the optimization procedure all buying station operating costs were assumed to be 32 cents per head. After the initial 32 cent per-head buying station costs solution, the recursive optimization procedure described in Chapter III was used to reach the optimum.

a. Solution procedure The recursive optimization procedure dictates that after each solution the buying station volumes are examined and costs are estimated using cost-volume Equation 7 so that they are consistent with the volume going through the station on the previous solution. The model is then resolved and the procedure continues until the costs agree with the volumes passing through the buying stations.

Seven recursive adjustments were needed before the optimum was obtained. Buying station volumes in the sixth and seventh solutions were the same and thus identified those buying station locations and volumes as the "optimal" according to the recursive procedure's criteria.

The volumes for each step through the procedure are shown in Table 21.

Table 21. Volume of each buying station at each stage in the recursive solution of Model I

LOCATION	VOLUME IN STAGE 1	2	3	4	5	6	7
149	3,489	0	0	0	0	0	0
150	4,412	0	0	0	0	0	0
151	2,015	0	0	0	0	0	0
152	0	0	0	0	0	0	0
153	8,481	0	0	0	0	0	0
154	4,109	0	0	0	0	0	0
155	13,009	4,747	0	0	0	0	0
156	12,714	2,917	0	0	0	0	0
157	22,646	27,110	46,216	55,894	55,894	55,894	55,894
158	1,983	0	0	0	0	0	0
159	7,897	0	0	0	0	0	0
160	25,457	22,955	14,829	14,829	14,829	14,829	14,829
161	5,929	0	0	0	0	0	0
162	5,399	0	0	0	0	0	0
163	6,447	0	0	0	0	0	0
164	13,622	0	0	0	0	0	0
165	14,352	0	0	0	0	0	0
166	4,189	0	0	0	0	0	0
167	4,325	0	0	0	0	0	0
168	11,222	0	0	0	0	0	0
169	17,081	17,081	17,081	17,081	17,081	17,081	17,081
170	11,127	6,421	3,104	0	0	0	0
171	12,542	8,078	7,663	5,756	0	0	0
172	16,846	25,916	33,839	43,768	54,225	59,187	59,187
173	7,789	4,701	0	0	0	0	0
174	10,972	3,425	0	0	0	0	0
175	12,480	0	0	0	0	0	0
176	33,687	34,087	31,586	25,798	22,853	22,853	22,853

Table 21 (Continued)

LOCATION	VOLUME IN STAGE						
	1	2	3	4	5	6	7
177	13,467	7,679	7,679	7,679	7,679	7,679	7,679
178	5,854	0	0	0	0	0	0
179	5,109	0	0	0	0	0	0
180	9,088	0	0	0	0	0	0
181	7,106	0	0	0	0	0	0
182	21,980	4,931	0	0	0	0	0
183	4,780	0	0	0	0	0	0
184	18,400	22,867	26,129	26,129	26,129	26,129	26,129
185	21,967	15,219	15,219	15,219	18,865	18,865	18,865
186	2,197	0	0	0	0	0	0
187	16,153	11,243	11,243	7,395	0	0	0
188	14,681	14,681	16,121	16,121	11,419	11,419	11,419
189	4,468	0	0	0	0	0	0
190	8,916	2,324	0	0	0	0	0
191	15,594	8,829	0	0	0	0	0
192	5,505	0	0	0	0	0	0
193	7,688	7,688	7,688	7,688	7,688	7,688	7,688
194	7,344	0	0	0	0	0	0
195	4,900	0	0	0	0	0	0
196	25,762	47,019	58,172	58,172	58,172	58,172	58,172
197	2,707	0	0	0	0	0	0
198	6,224	0	0	0	0	0	0
199	12,502	9,972	5,854	0	0	0	0
200	7,165	0	0	0	0	0	0

One strong note of caution needs to be inserted. As stated, the Broadbent-Perkinson data was used to estimate the cost adjusting relationship derived in Chapter IV. As noted, the relationship was estimated using least squares regression analysis on data obtained from 48 buying stations with yearly volume between 13 and 130 thousand head. Only 16 of the 51 buying stations operating in the initial solution were operating in the range for which the cost-volume relationship was estimated.

As discussed in Snedecor and Cochran (40, p. 155) the size of confidence limits about the dependent variable become larger as the value of the independent variable moves further from the mean.

Predicting values of the dependent variable outside the range of the original data is even more hazardous although equations for the variance of such predictions are available. The Broadbent-Perkinson relationship was not intended to be extrapolated for very low-volume buying operations. As a result, low-volume buying locations were generally eliminated early in the step-wise optimization procedure.

b. Results

1) Cost Total cost of efficiently moving the 2.5 million hogs produced in the area to 12 packing plants was $2.4 million dollars or approximately $0.93 per head.

2) Number, location and size of transhipment points Only 11 of the 52 transhipment points were operating in the optimal solution. The 11 stations handled between 7,600 and 60,000 head and averaged 27,000 head. In Figure 17 we find that the optimum set of buying stations are all located in the southern part of the area considered.

The southern locations of the buying stations resulted primarily because of the large plants located near the northern portion of the area so that all hogs produced in the northern part of the area are also sold to plants located near the area whereas some of the hogs produced in the southern part of the area are transhipped to plants located at Fort Dodge, Mason City, Dubuque and Davenport. Figure 18 shows the number and locations of the active buying stations.

3) Source of hogs transhipped All of the hogs transhipped were originally shipped in 16-head lots.

4) Destination of hogs transhipped The same seven plants that received hogs through transhipment points in the initial solution received hogs from transhipment points in the optimal solution. Fort Dodge, Dubuque, Mason City and Davenport received all of the hogs from the region through buying stations.

5) Total number transhipped Approximately 300 thousand, 11.68 per cent of the total marketed from the region, were shipped to plants through transhipment points.

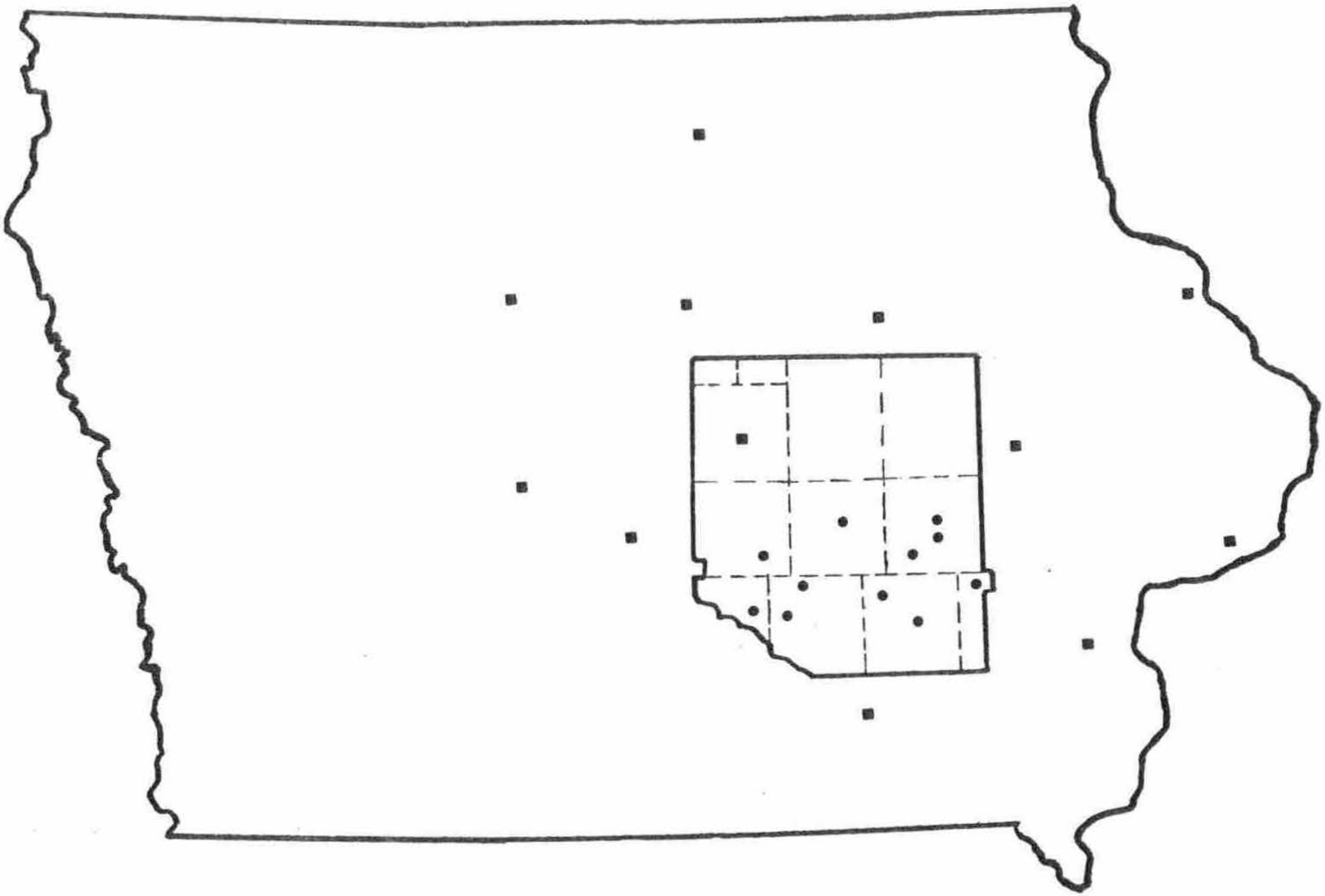

Figure 17. The optimal Model I location of buying stations in relation to packing plant locations. Key: • buying stations; ▪ packing plant locations

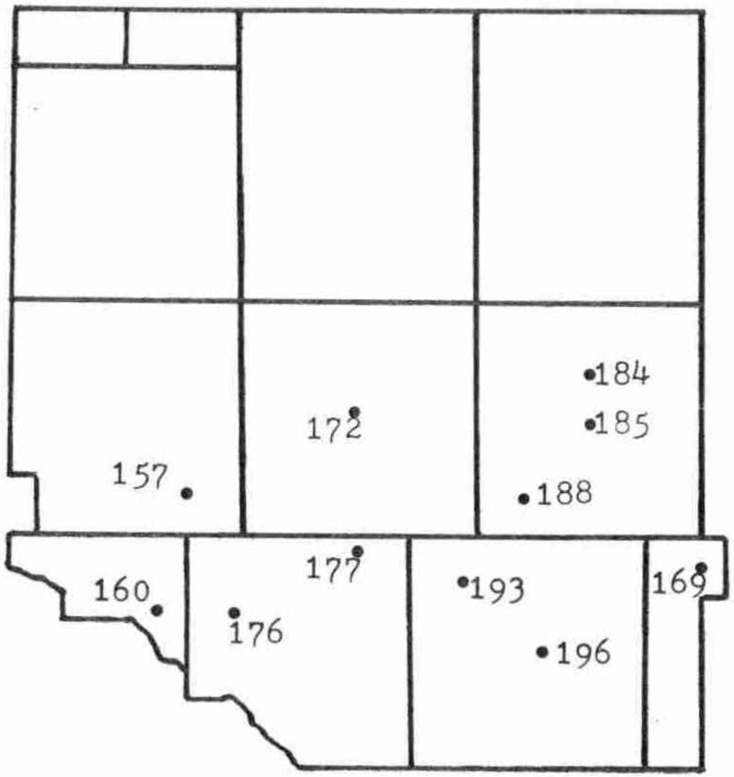

Figure 18. Location and number of the optimal Model I buying stations.

2. Real world approximation

The real world approximation is designed to estimate the marketing system as it is. In order to say the optimal solution is any better than the present system it is necessary to estimate the cost of the present system.

a. Procedure and assumptions The real world approximation estimates the least-cost shipment pattern if 70 per cent of the hogs produced in the area are shipped through transhipment points and 30 per cent are shipped direct to plants. According to packer procurement men contacted by telephone, approximately 30 per cent of the hogs slaughtered in the area are shipped direct to plants.

Also, it assumes that each buying location handles an equal proportion of the total transhipped or 34,500 head at \$0.57 cost per head the cost obtained when X_1 equals 34,500 in Equation 27.

It is important to note that the real world approximation can be said to determine the lowest cost transportation pattern given that 70 per cent of the hogs must be transhipped. Without doubt, the total cost of the current system is underestimated.

It is also assumed that only one buying station at each location is operating. There were 52 locations with registrants and 120 registrants. If 34,500 head pass through a transhipment location, the cost per head depends on the number of transhipment points operating. Thus, in a sense, the \$0.57 represents the lowest cost obtainable with 34,500 head passing through a location because it assumes that only one buying station is operating at each location.

One note of confidence in the assumed operating cost per head is in order. The Broadbent-Perkinson study found the average cost per head to be \$0.53, very near the cost assumed in my real world approximation.

b. Results

1) Cost   Total cost of the solution was \$3.1 million or \$1.19 per head.

2) Number, location and size of buying stations All buying stations were forced into the solution with 34,500 head volume.

3) Source of hogs transhipped   Hogs from all lot sizes were transhipped. Ninety-five per cent of the hogs shipped in pickup loads, 68 per cent of the hogs shipped in 30-head loads and 49 per cent of the hogs shipped in 45-head lots were transhipped.

4) Destination of hogs transhipped   Five of the twelve plants received 100 per cent of their supply from the region through transhipment points and one other plant received 98 per cent of its supply from transhipment points. All twelve plants received transhipped hogs.

5) Total transhipped Seventy per cent or 1.8 million hogs were transhipped.

B. Model II

Model II hypothesizes that hog production increases 10 per cent and that a greater per cent of hogs are marketed in larger lots. Table 20 summarizes the hypothesized conditions. Plants are assumed to receive the same percentages of total regional supply that are given in Table 13.

1. Solution procedure

The recursive, step-wise, optimization procedure used to solve for the optimal solution of Model I was again used. The eighth solution was the same as the seventh and identified the seventh solution as the "optimal" as defined by the procedure used. Table 22 lists the volume through each buying station at each stage in the solution process. In general, the comments directed toward the solution procedure in Section A also apply to the current solution as well.

2. Results

Only one of the solutions of Model II is discussed. Again, someone extremely skeptical of the Broadbent-Perkinson cost-volume relationship may want to attach great significance to the initial solution of Model II, where all buying stations are assumed to operate at $0.32 per head. What was said about the previous initial solution could be repeated here.

Table 22. Volume of each buying station at each stage in the recursive solution of Model II

LOCATION	VOLUME IN STAGE 1	2	3	4	5	6	7	8
149	2,791	0	0	0	0	0	0	0
150	3,529	0	0	0	0	0	0	0
151	1,611	0	0	0	0	0	0	0
152	0	0	0	0	0	0	0	0
153	6,785	0	0	0	0	0	0	0
154	3,287	0	0	0	0	0	0	0
155	10,407	3,797	0	0	0	0	0	0
156	10,171	2,333	0	0	0	0	0	0
157	18,117	21,687	28,138	36,640	43,128	44,715	44,715	44,715
158	1,586	0	0	0	0	0	0	0
159	6,317	0	0	0	0	0	0	0
160	20,365	11,863	11,863	11,863	11,863	11,863	11,863	11,863
161	4,742	0	0	0	0	0	0	0
162	4,319	0	0	0	0	0	0	0
163	5,157	0	0	0	0	0	0	0
164	10,897	0	0	0	0	0	0	0
165	6,738	0	0	0	0	0	0	0
166	3,351	0	0	0	0	0	0	0
167	3,459	0	0	0	0	0	0	0
168	8,977	0	0	0	0	0	0	0
169	13,664	13,664	13,664	13,664	13,664	13,664	13,664	13,664
170	8,901	5,136	2,483	0	0	0	0	0
171	10,033	9,529	9,529	9,529	7,671	3,067	0	0
172	13,476	18,385	23,473	29,555	35,014	39,618	39,618	39,618
173	6,230	3,761	0	0	0	0	0	0
174	8,777	2,740	0	0	0	0	0	0
175	9,984	0	0	0	0	0	0	0
176	32,234	33,770	33,770	25,268	18,282	18,282	18,282	18.282

Table 22 (Continued)

LOCATION	VOLUME IN STAGE							
	1	2	3	4	5	6	7	8
177	6,143	0	0	0	0	0	0	0
178	4,683	0	0	0	0	0	0	0
179	4,087	0	0	0	0	0	0	0
180	12,013	0	0	0	0	0	0	0
181	5,684	0	0	0	0	0	0	0
182	17,584	3,945	0	0	0	0	0	0
183	3,823	0	0	0	0	0	0	0
184	14,719	13,348	13,348	13,348	13,348	13,348	13,348	13,348
185	15,481	12,175	12,175	12,175	12,175	15,092	15,092	15,092
186	3,849	0	0	0	0	0	0	0
187	12,922	11,784	8,994	8,994	5,916	0	0	0
188	11,744	11,302	15,505	15,505	15,505	15,505	15,505	15,505
189	3,574	0	0	0	0	0	0	0
190	7,132	0	0	0	0	0	0	0
191	12,475	7,063	0	0	0	0	0	0
192	4,403	0	0	0	0	0	0	0
193	6,150	6,150	6,150	6,150	6,150	6,150	6,150	6,150
194	5,875	0	0	0	0	0	0	0
195	3,919	0	0	0	0	0	0	0
196	20,609	37,615	44,678	46,537	46,537	46,537	46,537	46,537
197	2,165	0	0	0	0	0	0	0
198	4,979	0	0	0	0	0	0	0
199	10,001	4,683	0	0	0	0	0	0
200	5,732	0	0	0	0	0	0	0

The same five data elements used to summarize the Model I solutions will be used to summarize the results of Model II.

a. Cost   Approximately 2.8 million head were marketed for $2.48 million dollars or approximately $0.88 per head.

b. Number, location and size of transhipment points Ten of the 52 buying locations handled hogs. The only buying location that was active in the optimal solution of Model I that was not active in the optimal solution of Model II was 177. The buying stations ranged in size from 6,150 to 46,537 head and averaged 22,478 head.

c. Source of hogs transhipped   All of the hogs transhipped originated in pickup truck sized loads. Almost 44 per cent of the hogs shipped in pickup loads were transhipped.

d. Destination of hogs transhipped   Half of the plants receiving hogs from the region received hogs from transhipment locations. Four plants (Fort Dodge, Mason City, Davenport and Dubuque) received 100 per cent of their hogs from the region through transhipment points.

e. Total transhipped   Approximately 225 thousand hogs or eight per cent of the total assumed marketings were shipped through transhipment points.

VI. CONCLUSIONS

A. Model Comparisons

Two basic comparisons were made. First, the real world and optimal solutions of Model I (present production levels) were compared to measure the extent of possible operational efficiency improvements in the current marketing structure. The basic question is how much more cheaply could hogs from the region be moved to plants by changing the location, number and size of buying stations in the region?

Second, the optimal solutions of Model I and Model II were compared to ascertain whether the increased production and the shift to larger lot sizes specified in Model II dictates a significantly different marketing structure. In other words, how sensitive was the best solution to basic production changes?

1. The real world versus the "best"

In Table 23 it is shown that the average cost for shipping hogs from the region to plants could be quite low--even making the restrictive real world assumptions of Model I. However, by reorganizing the location, number and size of buying stations, marketing costs could be reduced 26 cents per head or 22 per cent.

a. Actual or attainable cost It must be noted that both solutions specify the least-cost shipment of hogs given a certain number, size and location of buying stations. It

Table 23. Total cost, volume marketed and cost per head for Model I and Model II

	MODEL I		MODEL II
	OPTIMAL	REAL WORLD	
Total marketing cost	$2,379,980	$3,053,059	$2,478,870
Total number marketed	$2,566,595	$2,566,595	$2,823,255
Total cost per head	$0.93	$1.19	$0.88

cannot be said that the cost per head would be lower if the structure of industry were changes. It can only be said that the cost could be lower. The actual cost of any specified structure depends on how producers use it. Thus, even though the attainable cost was lower in the best solution, the actual cost may not be.

Therefore, in order to say that the lower cost structure is better than the higher cost marketing structure it is necessary to assume that because the attainable cost is lower, obtained or actual cost will be lower. This will not always be the case as long as we assume independent producer decision making within the structure.

b. Southern buying station locations The buying stations in the least-cost solution of Model I were located in the southern part of the region. In general this was caused by the large demand points located near the northern part of the area and the smaller plants located within the northern

Table 24. Destination of hogs shipped through buying stations

	MODEL I				MODEL II	
	OPTIMAL		REAL WORLD			
PLANT LOCATION	NUMBER	PER CENT OF PLANT'S DEMAND	NUMBER	PER CENT OF PLANT'S DEMAND	NUMBER	PER CENT OF PLANT'S DEMAND
201	23,864	3.32	481,746	67.03	0	0.00
202	0	0.00	121,480	63.10	0	0.00
203	0	0.00	34,500	26.86	0	0.00
204	0	0.00	35,498	23.05	0	0.00
205	0	0.00	75,402	36.72	0	0.00
206	66,866	9.30	600,075	58.69	22,880	2.89
207	29,426	14.33	201,499	98.13	4,296	1.90
208	51,330	100.00	51,330	100.00	56,463	100.00
209	64,160	100.00	64,160	100.00	70,576	100.00
210	0	0.00	64,160	100.00	0	0.00
211	25,660	100.00	25,660	100.00	28,226	100.00
212	38,490	100.00	38,490	100.00	42,339	100.00
Total	299,796		1,794,000		224,774	
Per Cent Transhipped	11.68		70.00		7.96	

part of the area. Thus, all of the hogs shipped from the northern tiers of townships were shipped directly to nearby plants.

Hogs shipped from the southern part of the region to plants located north of the region were transhipped. As shown in Table 25, all of the hogs transhipped were originally shipped in 16-head loads.

This implies that it may be easier for a plant wanting to buy hogs from more than 60 miles away to buy small lots and make provisions for transhipment. The conclusion seems somewhat consistent with the locational pattern of packer buying stations shown in Figure 1. The relationship is further reinforced by the fact that many of the packer-owned buying stations in Figure 1 that are located near plants are not owned by the nearby plant.

The relationship is most evident in Black Hawk, Wapello, Linn, Marshall and Polk counties. There are no packer-owned buying stations in either Wapello or Black Hawk county. The buying stations in Marshall, Polk, Hardin and Linn are not owned by the packer located in that county.

c. Cost reduction--significant or not significant

It was surprising to find that 70 per cent of the hogs could be shipped through buying stations while raising marketing cost per head by only 26 cents. To the individual producer, this represents approximately 11 cents more return per one

Table 25. Source of hogs transhipped through buying stations

LOT SIZE	MODEL I				MODEL II	
	OPTIMUM		REAL WORLD			
	NUMBER TRANSHIPPED	PER CENT	NUMBER TRANSHIPPED	PER CENT	NUMBER TRANSHIPPED	PER CENT
16-Head	299,796	46.71	611,959	95.37	224,774	43.78
30-Head	0	0.00	868,226	67.65	0	0.00
45-Head	0	0.00	313,815	48.90	0	0.00
Total	299,796		1,794,000		224,774	

hundred pounds. It is doubtful that 11 cents is enough to convince the producer or this researcher that the system should be changed. It is likely the producer would argue that additional buying stations tend to make the hog buying atmosphere more competitive and therefore the cost of additional buying stations is more than offset by higher prices. It was not possible to refute his claim because of operational efficiency gains.

2. Model I versus Model II

Model I and Model II were solved using the same recursive search procedure.

Table 26 shows that all except one of the buying stations operating in Model I were also operating in Model II. The eliminated buying station was a very low volume, high cost buying station.

The most significant factor was that the buying stations operated at lower volume in Model II than in Model I. Thus, although more hogs were marketed, a smaller number was transhipped because fewer hogs were shipped in 16-head lots.

As a consequence of the lower volume and associated higher cost buying stations, the solution to Model II specified that a larger per cent of the hogs shipped in 16-head loads be shipped through buying stations.

To reiterate, as a result of assuming that a smaller number of hogs were shipped in 16-head loads, a smaller per cent of the 16-head shipments were funneled through buying stations.

A caution needs to be added. It was shown in Table 8 that a shift toward more hog marketings per farm is taking place. However, this does not necessarily mean that hogs will be marketed in larger loads. Evidence about how the shift toward larger production units affects the size of marketing units was not available.

It has been shown that increasing the per cent of hogs shipped in larger loads will cause the size and eventually the number of buying stations needed for a least-cost shipment structure to decline.

B. Conclusions

The following conclusions are logical:

1. A marketing structure with fewer, large-volume buying

Table 26. Volume of each of the buying stations in Model I and Model II

BUYING STATION NUMBER	MODEL I OPTIMAL	MODEL I REAL WORLD APPROXIMATION	MODEL II
149	0	34,500	0
150	0	34,500	0
151	0	34,500	0
152	0	34,500	0
153	0	34,500	0
154	0	34,500	0
155	0	34,500	0
156	0	34,500	0
157	55,894	34,500	44,715
158	0	34,500	0
159	0	34,500	0
160	14,829	34,500	11,864
161	0	34,500	0
162	0	34,500	0
163	0	34,500	0
164	0	34,500	0
165	0	34,500	0
166	0	34,500	0
167	0	34,500	0
168	0	34,500	0
169	17,081	34,500	13,664
170	0	34,500	0
171	0	34,500	0
172	59,187	34,500	39,618
173	0	34,500	0
174	0	34,500	0
175	0	34,500	0
176	22,853	34,500	18,282
177	7,679	34,500	0
178	0	34,500	0
179	0	34,500	0
180	0	34,500	0
181	0	34,500	0
182	0	34,500	0
183	0	34,500	0
184	26,129	34,500	13,348
185	18,865	34,500	15,092
186	0	34,500	0
187	0	34,500	0
188	11,419	34,500	15,505

Table 26 (Continued)

BUYING STATION NUMBER	MODEL I OPTIMAL	MODEL I REAL WORLD APPROXIMATION	MODEL II
189	0	34,500	0
190	0	34,500	0
191	0	34,500	0
192	0	34,500	0
193	7,688	34,500	6,150
194	0	34,500	0
195	0	34,500	0
196	58,172	34,500	46,537
197	0	34,500	0
198	0	34,500	0
199	0	34,500	0
200	0	34,500	0
Total Transhipped	299,796	1,794,000	224,774
Per Cent Transhipped	11.68	70.00	7.96
Average Buying Station Size	27,254	34,500	22,478

stations would be more operationally efficient than the current marketing system.

2. The operational efficiency gains may not offset pricing efficiency losses.
3. A shift toward shipments in larger lots would tend to decrease the number and size of buying stations needed to move hogs to plants at least cost.
4. Methods for improving buying competition for hogs should be sought that do not involve local dealers

and order buyers.

5. Packer buyers should emphasize plant delivery of hogs.

1. Additional research suggestions

Operational efficiency research on decentralized hog procurement in Iowa will not provide results that will motivate acceptance of revised marketing systems. Therefore it is not recommended that the model presented be adapted to a larger production region. The 11 cents per head savings would not justify the expense of operationalizing a statewide model.

Efforts should be directed toward analyzing alternative marketing systems designed to improve pricing efficiency. Can a teletype auction be successful in Iowa? How much would it cost? How would it effect prices? What kind of grading system would make competitive bidding feasible without physically handling or moving hogs to a central location?

What market channel characteristics do producers feel are important enough to be included in a proposed marketing system?

2. Other possible uses of the buying station location model

Slaughter plants could easily make use of a buying station location model if they can specify supply areas and are contemplating relocating or eliminating some of their buying stations. Which location pattern would make the procurement operation most operationally efficient?

Also, producer marketing groups with contracts with packers and producers could determine which producer's hogs should be shipped through which collection points as well as the profitability of opening additional collection points. If desired, the model could be restricted to require all of the hogs to be transhipped.

The general form of the model and the solution procedure are applicable to numerous business decisions with regard to any intermediate production, wholesaling, warehousing or retailing operation. In general, the solution tells if intermediate points are necessary, where they should be, how large they should be and who they should serve.

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A thesis is never an easy undertaking. Somehow theses are written, read and eventually students receive degrees. But, by that time the volume has touched the lives of many people other than the student receiving the degree. The lives of many other people have been affected by this volume in the past two years.

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APPENDIX A. NUMERICAL KEY TO TOWNSHIPS AND COUNTIES

Table 27. Townships, counties and their assigned numbers

NUMBER	COUNTY	TOWNSHIP
1	Hardin	Providence
2	Hardin	Union
3	Grundy	Felix
4	Grundy	Clay
5	Marshall	Liberty
6	Marshall	Bangor
7	Marshall	Liscomb
8	Marshall	Vienna
9	Marshall	Minerva
10	Marshall	Marietta
11	Marshall	Iowa
12	Marshall	Taylor
13	Marshall	Marion
14	Marshall	Linn
15	Marshall	State Center
16	Marshall	Washington
17	Marshall	Timber Creek
18	Marshall	Le Grand
19	Marshall	Eden
20	Marshall	Logan
21	Marshall	Jefferson
22	Marshall	Green Castle
23	Jasper	Independence
24	Jasper	Malaka
25	Jasper	Mariposa
26	Jasper	Hickory Grove
27	Jasper	Sherman
28	Jasper	Newton
29	Jasper	Kellogg
30	Jasper	Rock Creek
31	Jasper	Mound Prairie
32	Jasper	Palo Alto
33	Jasper	Buena Vista
34	Jasper	Richland
35	Jasper	Fair View
36	Jasper	Elk Creek
37	Jasper	Lynn Grove
38	Marion	Red Rock
39	Marion	Summit
40	Marion	Lake Prairie
41	Tama	Lincoln
42	Tama	Grant
43	Tama	Buckingham
44	Tama	Geneseo

Table 27 (Continued)

NUMBER	COUNTY	TOWNSHIP
45	Tama	Spring Creek
46	Tama	Crystal
47	Tama	Perry
48	Tama	Clark
49	Tama	Carlton
50	Tama	Howard
51	Tama	Carroll
52	Tama	Oneida
53	Tama	Indian Village
54	Tama	Toledo
55	Tama	Otter Creek
56	Tama	York
57	Tama	Highland
58	Tama	Columbia
59	Tama	Richland
60	Tama	Salt Creek
61	Poweshiek	Chester
62	Poweshiek	Sheridan
63	Poweshiek	Madison
64	Poweshiek	Jefferson
65	Poweshiek	Grant
66	Poweshiek	Malcom
67	Poweshiek	Bear Creek
68	Poweshiek	Warren
69	Poweshiek	Washington
70	Poweshiek	Pleasant
71	Poweshiek	Scott
72	Poweshiek	Lincoln
73	Poweshiek	Sugar Creek
74	Poweshiek	Union
75	Poweshiek	Jackson
76	Poweshiek	Deep River
77	Mahaska	Richland
78	Mahaska	Prairie
79	Mahaska	Union
80	Mahaska	Pleasant Grove
81	Mahaska	Black Oak
82	Mahaska	Madison
83	Mahaska	Adams
84	Mahaska	Monroe
85	Mahaska	Scott
86	Mahaska	Garfield
87	Mahaska	Spring Creek
88	Mahaska	White Oak

Table 27 (Continued)

NUMBER	COUNTY	TOWNSHIP
89	Mahaska	East Des Moines
90	Mahaska	Harrison
91	Mahaska	Cedar
92	Benton	Bruce
93	Benton	Cedar
94	Benton	Harrison
95	Benton	Polk
96	Benton	Monroe
97	Benton	Jackson
98	Benton	Taylor
99	Benton	Benton
100	Benton	Homer
101	Benton	Big Grove
102	Benton	Eden
103	Benton	Canton
104	Benton	Kane
105	Benton	Union
106	Benton	El Dorado
107	Benton	Fremont
108	Benton	Iowa
109	Benton	Leroy
110	Benton	St. Clair
111	Benton	Florence
112	Iowa	Honey Creek
113	Iowa	Marengo
114	Iowa	Washington
115	Iowa	Lenox
116	Iowa	Hartford
117	Iowa	Sumner
118	Iowa	Hilton
119	Iowa	Iowa
120	Iowa	Lincoln
121	Iowa	Pilot
122	Iowa	Troy
123	Iowa	York
124	Iowa	Dayton
125	Iowa	English
126	Iowa	Filmore
127	Iowa	Greene
128	Keokuk	Prairie
129	Keokuk	Adams
130	Keokuk	English River
131	Keokuk	Liberty
132	Keokuk	Lime Creek

Table 27 (Continued)

NUMBER	COUNTY	TOWNSHIP
133	Keokuk	Van Buren
134	Keokuk	Plank
135	Keokuk	La Fayette
136	Keokuk	Warren
137	Keokuk	Sigourney
138	Keokuk	West Lancaster
139	Keokuk	East Lancaster
140	Keokuk	Clear Creek
141	Keokuk	Benton
142	Keokuk	Steady Run
143	Keokuk	Jackson
144	Keokuk	Richland
145	Washington	Lime Creek
146	Washington	Seventy Six
147	Washington	Dutch Creek
148	Washington	Clay

APPENDIX B. NUMERICAL KEY TO TRANSHIPMENT POINTS: LOCATION AND TYPE

Table 28. Transhipment points: location, number and type

LOCATION	TOWN	PRIVATE DEALERS AND ORDER BUYERS	COMPANY OPERATED BUYING STATIONS	AUCTION BARNS
149	Beaman	1	0	0
150	New Providence	1	0	0
151	Le Grand	0	1	0
152	Marshalltown	4	0	1
153	Gilman	2	0	0
154	State Center	2	0	0
155	Newton	0	2	0
156	Baxter	0	0	1
157	Sully	2	0	0
158	Kellogg	2	0	0
159	Monroe	1	0	0
160	Pella	9	0	1
161	Otley	1	0	0
162	Tama	2	1	1
163	Toledo	2	1	0
164	Traer	0	0	1
165	Clutier	1	0	0
166	Chelsea	2	1	0
167	Gladbrook	1	1	0
168	Lincoln	0	1	0
169	Wellman	1	0	0
170	Grinnell	6	1	1
171	Montezuma	0	1	1
172	Brooklyn	1	1	0
173	Deep River	3	1	0
174	Malcom	1	0	0
175	Oskaloosa	2	1	1
176	Leighton	1	1	0
177	Barnes City	0	1	0
178	New Sharon	2	0	1
179	Belle Plaine	1	1	1
180	Keystone	0	1	0
181	Vinton	4	0	0
182	Garrison	1	0	1
183	Van Horne	2	0	0
184	Williamsburg	0	2	0
185	Conroy	0	1	0
186	Marengo	1	0	1
187	Ladora	2	0	0
188	Millersburg	1	0	0

Table 28 (Continued)

LOCATION	TOWN	PRIVATE DEALERS AND ORDER BUYERS	COMPANY OPERATED BUYING STATIONS	AUCTION BARNS
189	North English	3	0	0
190	Sigourney	1	2	1
191	Keota	2	1	0
192	South English	1	1	0
193	Keswick	0	1	0
194	Richland	0	1	0
195	Ollie	0	0	1
196	Harper	1	0	0
197	Hedrick	1	0	0
198	Kinross	1	0	0
199	What Cheer	1	0	0
200	Gifford	1	0	0

APPENDIX C. NUMERICAL KEY TO COUNTIES AND FIVE-YEAR COUNTY PIG PRODUCTION DATA

Table 29. Five year county pig farrowing data and averages for the 12 counties included in the region studied (47, p. 6-7)

COUNTY NUMBER	COUNTY	1966	1967	1968	1969	1970	AVERAGE
1	Hardin	277,500	293,000	271,000	239,500	288,700	273,940
2	Grundy	217,800	244,000	244,200	218,000	240,300	232,860
3	Marshall	193,000	203,300	220,200	198,400	206,200	204,220
4	Jasper	310,800	300,100	329,800	302,700	346,300	317,940
5	Marion	217,500	220,500	251,200	221,500	266,600	235,460
6	Tama	286,000	291,200	319,000	275,600	318,500	298,060
7	Poweshiek	230,300	248,400	276,400	244,500	278,700	255,660
8	Mahaska	303,800	318,800	361,200	337,500	361,700	336,600
9	Benton	358,600	407,900	361,900	314,100	355,400	359,580
10	Iowa	317,900	325,900	375,900	333,700	344,000	339,480
11	Keokuk	307,300	310,300	353,100	331,300	373,600	335,120
12	Washington	426,100	420,700	448,900	421,200	460,300	435,440

APPENDIX D. ADJUSTMENTS MADE ON SUPPLY DATA

Table 30. Data used to determine the number of hogs available from each township

TOWNSHIP	AVERAGE COUNTY FARROWING[1] (CSF_i)	COUNTY FARROWING ADJUSTED FOR DEATH LOSSES, INSHIPMENTS AND OUTSHIPMENTS[2]	COUNTY MARKETING[3] (CM_i^*)	TOWNSHIP MARKETING[4] (TM_{ij}^*)	PER CENT OF COUNTY MARKETING $(\frac{TM_{ij}^*}{CM_i^*})$	QUANTITY AVAILABLE (TM_{ij})
1	273,940	266,867	214,242	23,009	10.7	28,661
2	273,940	266,867	214,242	14,168	6.6	17,648
3	232,860	226,848	182,495	8,988	4.9	11,172
4	232,860	226,848	182,495	11,228	6.2	13,957
5	204,220	198,947	163,045	13,472	8.3	16,438
6	204,220	198,947	163,045	8,145	5.0	9,939
7	204,220	198,947	163,045	3,810	2.3	4,649
8	204,220	198,947	163,045	11,158	6.8	13,615
9	204,220	198,947	163,045	16,039	9.8	19,571
10	204,220	198,947	163,045	11,726	7.2	14,308
11	204,220	198,947	163,045	4,349	2.7	5,307
12	204,220	198,947	163,045	5,517	3.4	6,732
13	204,220	198,947	163,045	6,730	4.1	8,212
14	204,220	198,947	163,045	1	0.0	1

[1]From Table 29.

[2]Death adjustment and inshipment and outshipment factors from (51, p. 34).

[3](18, p. 30-31).

[4]Sutherland, Roger, Agricultural Statistician in Charge. Iowa Crop and Livestock Reporting Service, Des Moines, Iowa. Data from county assessors reports used to compile the Iowa Farm Census. Private communication. 1970.

Table 30 (Continued)

TOWNSHIP	AVERAGE COUNTY FARROWING[1] (CSF_i)	COUNTY FARROWING ADJUSTED FOR DEATH LOSSES, INSHIPMENTS AND OUTSHIPMENTS[2]	COUNTY MARKETING[3] (CM_i*)	TOWNSHIP MARKETING[4] (TM_{ij}*)	PER CENT OF COUNTY MARKETING $\left(\frac{TM_{ij}*}{CM_i*}\right)$	QUANTITY AVAILABLE (TM_{ij})
15	204,220	198,947	163,045	13,030	8.0	15,899
16	204,220	198,947	163,045	9,223	5.7	11,254
17	204,220	198,947	163,045	10,408	6.4	12,700
18	204,220	198,947	163,045	8,636	5.3	10,538
19	204,220	198,947	163,045	8,835	5.4	10,780
20	204,220	198,947	163,045	12,404	7.6	15,135
21	204,220	198,947	163,045	10,460	6.4	12,763
22	204,220	198,947	163,045	8,239	5.1	10,053
23	317,940	309,731	261,979	9,868	3.8	11,667
24	317,940	309,731	261,979	15,258	5.8	18,039
25	317,940	309,731	261,979	9,292	3.5	10,986
26	317,940	309,731	261,979	12,127	4.6	14,337
27	317,940	309,731	261,979	8,772	3.3	10,371
28	317,940	309,731	261,979	8,139	3.1	9,623
29	317,940	309,731	261,979	9,868	3.8	11,667
30	317,940	309,731	261,979	6,710	2.6	7,933
31	317,940	309,731	261,979	11,741	4.5	13,881
32	317,940	309,731	261,979	9,946	3.8	11,759
33	317,940	309,731	261,979	16,061	6.1	18,988
34	317,940	309,731	261,979	16,061	9.0	27,997
35	317,940	309,731	261,979	20,263	7.7	23,956
36	317,940	309,731	261,979	21,540	8.2	25,466
37	317,940	309,731	261,979	31,400	12.0	37,123

Table 30 (Continued)

TOWNSHIP	AVERAGE COUNTY FARROWING[1] (CSF_i)	COUNTY FARROWING ADJUSTED FOR DEATH LOSSES, INSHIPMENTS AND OUTSHIPMENTS[2]	COUNTY MARKETING[3] (CM_i*)	TOWNSHIP MARKETING[4] (TM_{ij}*)	PER CENT OF COUNTY MARKETING $\left(\frac{TM_{ij}^*}{CM_i^*}\right)$	QUANTITY AVAILABLE (TM_{ij})
38	235,460	229,380	155,868	5,186	3.3	7,632
39	235,460	229,380	155,868	16,115	10.3	23,715
40	235,460	229,380	155,868	40,307	25.9	59,317
41	298,060	290,364	258,341	23,066	8.9	25,925
42	298,060	290,364	258,341	16,873	6.5	18,965
43	298,060	290,364	258,341	12,905	5.0	14,505
44	298,060	290,364	258,341	14,646	5.7	16,461
45	298,060	290,364	258,341	15,392	6.0	17,300
46	298,060	290,364	258,341	14,590	5.6	16,399
47	298,060	290,364	258,341	12,480	4.8	14,027
48	298,060	290,364	258,341	21,407	8.3	24,061
49	298,060	290,364	258,341	12,242	4.7	13,759
50	298,060	290,364	258,341	17,653	6.8	19,841
51	298,060	290,364	258,341	14,519	5.6	16,319
52	298,060	290,364	258,341	15,459	6.0	17,375
53	298,060	290,364	258,341	7,171	2.8	8,060
54	298,060	290,364	258,341	5,290	2.0	5,946
55	298,060	290,364	258,341	8,338	3.2	9,372
56	298,060	290,364	258,341	12,040	4.7	13,532
57	298,060	290,364	258,341	8,484	3.3	9,536
58	298,060	290,364	258,341	10,877	4.2	12,225
59	298,060	290,364	258,341	10,592	4.1	11,905
60	298,060	290,364	258,341	4,317	1.7	4,852

Table 30 (Continued)

TOWNSHIP	AVERAGE COUNTY FARROWING[1] (CSF_i)	COUNTY FARROWING ADJUSTED FOR DEATH LOSSES, INSHIPMENTS AND OUTSHIPMENTS[2]	COUNTY MARKETING[3] (CM_i*)	TOWNSHIP MARKETING[4] (TM_{ij}*)	PER CENT OF COUNTY MARKETING $\left(\frac{TM_{ij}*}{CM_i*}\right)$	QUANTITY AVAILABLE (TM_{ij})
61	255,660	249,059	196,073	14,821	7.6	18,826
62	255,660	249,059	196,073	14,164	7.2	17,992
63	255,660	249,059	196,073	15,439	7.9	19,611
64	255,660	249,059	196,073	9,239	4.7	11,736
65	255,660	249,059	196,073	9,776	5.0	12,418
66	255,660	249,059	196,073	9,602	4.9	12,197
67	255,660	249,059	196,073	16,473	8.4	20,925
68	255,660	249,059	196,073	10,675	5.4	13,560
69	255,660	249,059	196,073	10,443	5.3	13,265
70	255,660	249,059	196,073	10,786	5.5	13,701
71	255,660	249,059	196,073	10,460	5.3	13,287
72	255,660	249,059	196,073	9,722	5.0	12,349
73	255,660	249,059	196,073	14,056	7.2	17,854
74	255,660	249,059	196,073	7,314	3.7	9,290
75	255,660	249,059	196,073	18,126	9.2	23,024
76	255,660	249,059	196,073	14,805	7.6	18,806
77	336,600	327,909	291,391	37,778	13.0	42,512
78	336,600	327,909	291,391	20,572	7.1	23,150
79	336,600	327,909	291,391	13,628	4.7	15,336
80	336,600	327,909	291,391	13,669	4.7	15,382
81	336,600	327,909	291,391	35,573	12.2	40,031
82	336,600	327,909	291,391	15,810	5.4	17,791
83	336,600	327,909	291,391	10.467	3.6	11,779

Table 30 (Continued)

TOWNSHIP	AVERAGE COUNTY FARROWING[1] (CSF_i)	COUNTY FARROWING ADJUSTED FOR DEATH LOSSES, INSHIPMENTS AND OUTSHIPMENTS[2]	COUNTY MARKETING[3] (CM_i^*)	TOWNSHIP MARKETING[4] (TM_{ij}^*)	PER CENT OF COUNTY MARKETING ($\frac{TM_{ij}^*}{CM_i^*}$)	QUANTITY AVAILABLE (TM_{ij})
84	336,600	327,909	291,391	19,070	6.5	21,460
85	336,600	327,909	291,391	16,122	5.5	18,142
86	336,600	327,909	291,391	13,729	4.7	15,450
87	336,600	327,909	291,391	17,711	6.1	19,931
88	336,600	327,909	291,391	16,930	5.8	19,052
89	336,600	327,909	291,391	2,454	0.8	2,762
90	336,600	327,909	291,391	17,490	6.0	19,682
91	336,600	327,909	291,391	17,044	5.8	19,180
92	359,580	350,296	279,138	21,035	7.5	26,397
93	359,580	350,296	279,138	18,963	6.8	23,797
94	359,580	350,296	279,138	14,247	5.1	17,879
95	359,580	350,296	279,138	11,524	4.1	14,462
96	359,580	350,296	279,138	16,379	5.9	20,554
97	359,580	350,296	279,138	15,719	5.6	19,726
98	359,580	350,296	279,138	8,402	3.0	10,544
99	359,580	350,296	279,138	5,404	1.9	6,782
100	359,580	350,296	279,138	18,897	6.8	23,714
101	359,580	350,296	279,138	19,001	6.8	23,845
102	359,580	350,296	279,138	21,751	7.8	27,296
103	359,580	350,296	279,138	11,239	4.0	14,104
104	359,580	350,296	279,138	18,186	6.5	22,822
105	359,580	350,296	279,138	15,236	5.5	19,120
106	359,580	350,296	279,138	10,015	3.6	12,568

Table 30 (Continued)

TOWNSHIP	AVERAGE COUNTY FARROWING[1] (CSF_i)	COUNTY FARROWING ADJUSTED FOR DEATH LOSSES, INSHIPMENTS AND OUTSHIPMENTS[2]	COUNTY MARKETING[3] (CM_i*)	TOWNSHIP MARKETING[4] (TM_{ij}*)	PER CENT OF COUNTY MARKETING ($\frac{TM_{ij}*}{CM_i*}$)	QUANTITY AVAILABLE (TM_{ij})
107	359,580	350,296	279,138	12,932	4.6	16,229
108	359,580	350,296	279,138	6,933	2.5	8,700
109	359,580	350,296	279,138	11,622	4.2	14,585
110	359,580	350,296	279,138	13,164	4.7	16,520
111	359,580	350,296	279,138	8,489	3.0	10,653
112	339,480	330,715	269,572	12,224	4.5	14,997
113	339,480	330,715	269,572	7,165	2.7	8,790
114	339,480	330,715	269,572	8,526	3.2	10,460
115	339,480	330,715	269,572	7,859	2.9	9,642
116	339,480	330,715	269,572	12,545	4.7	15,390
117	339,480	330,715	269,572	16,009	5.9	19,640
118	339,480	330,715	269,572	20,147	7.5	24,717
119	339,480	330,715	269,572	29,485	10.9	36,173
120	339,480	330,715	269,572	10,634	3.9	13,046
121	339,480	330,715	269,572	17,149	6.4	21,039
122	339,480	330,715	269,572	22,689	8.4	27,835
123	339,480	330,715	269,572	20,154	7.5	24,725
124	339,480	330,715	269,572	17,038	6.3	20,902
125	339,480	330,715	269,572	20,195	7.5	24,775
126	339,480	330,715	269,572	14,567	5.4	17,871
127	339,480	330,715	269,572	33,186	12.3	40,713
128	335,120	326,467	265,750	19,062	7.2	23,417
129	335,120	326,467	265,750	25,034	9.4	30,754

Table 30 (Continued)

TOWNSHIP	AVERAGE COUNTY FARROWING[1] (CSF_i)	COUNTY FARROWING ADJUSTED FOR DEATH LOSSES, INSHIPMENTS AND OUTSHIPMENTS[2]	COUNTY MARKETING[3] (CM_i*)	TOWNSHIP MARKETING[4] (TM_{ij}*)	PER CENT OF COUNTY MARKETING ($\frac{TM_{ij}*}{CM_i*}$)	QUANTITY AVAILABLE (TM_{ij})
130	335,120	326,467	265,750	17,925	6.7	22,020
131	335,120	326,467	265,750	20,267	7.6	24,897
132	335,120	326,467	265,750	13,409	5.0	16,473
133	335,120	326,467	265,750	13,025	4.9	16,001
134	335,120	326,467	265,750	27,208	10.2	33,424
135	335,120	326,467	265,750	25,107	9.4	30,843
136	335,120	326,467	265,750	9,830	3.7	12,076
137	335,120	326,467	265,750	7,568	2.8	9,297
138	335,120	326,467	265,750	8,438	3.2	10,366
139	335,120	326,467	265,750	5,920	2.2	7,273
140	335,120	326,467	265,750	31,568	11.9	38,780
141	335,120	326,467	265,750	10,460	3.9	12,850
142	335,120	326,467	265,750	8,816	3.3	10,830
143	335,120	326,467	265,750	10,034	3.8	12,327
144	335,120	326,467	265,750	12,079	4.5	14,839
145	435,440	424,197	327,761	21,333	6.5	27,610
146	435,440	424,197	327,761	27,287	8.3	35,316
147	435,440	424,197	327,761	20,909	6.4	27,061
148	435,440	424,197	327,761	11,234	3.4	14,539